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# MILITARY STANDARDIZATION HANDBOOK
# GENERATOR SETS, ELECTRICAL, MEASUREMENTS AND INSTRUMENTATIONS

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## WASHINGTON 25, D.C.

MIL–HDBK–705A
Generator Sets, Electrical, Measurements and Instrumentations

1. This standardization handbook has been approved by the Department of Defense for use by the Departments of the Army, the Navy, and the Air Force.

2. In accordance with established procedure, the Corps of Engineers, Bureau of Yards and Docks, and Air Force have been designated as the Army-Navy-Air Force Custodians of this handbook.

3. Recommended corrections, additions, or deletions should be addressed to the Defense Logistics Services Center, Washington 25, D.C.

# FOREWORD

1. This handbook is intended to explain and establish terminology, instrumentation, method of measurement and accepted procedure associated with the evaluation of electric generators, generator sets, and related components to determine compliance with the desired characteristics represented by procurement documents. The general methods of test are included herein, while the many specific methods of test are established in MIL–STD–705, Generator Sets, Engine-Driven, Methods of Tests and Instructions.

2. This handbook is closely allied to MIL–STD–705 and references from one to the other are freely used particularly from MIL–STD–705 to this document. Inspectors will find need for both the handbook and standard when working on electric generator equipment.

3. Due to the complexity of specified requirements in purchase documents covering engine-driven electric generators and other similar types of electric machinery, military personnel will find this handbook especially helpful as a convenient source of general information on electrical instruments and their proper use. This technology has been documented from the past several years experience by government engineers in dealing with the procurement of the subject equipment.

## CONTENTS

1. SCOPE
1.1 COVERAGE
1.2 NUMBERING SYSTEM
1.2.1 METHOD NUMBERS
1.2.2 DECIMAL SYSTEM
2. REFERENCED DOCUMENTS
3. DEFINITIONS
4. INSTRUMENTS AND MEASUREMENTS 100 SERIES
5. INSTRUMENTATION AND GENERAL TEST METHODS 200 SERIES
6. ALPHABETICAL INDEX OF TEST METHODS
7. NUMERICAL INDEX OF TEST METHODS

# 1. SCOPE

## 1.1 Coverage

This handbook covers a compilation of electrical term definitions and two series of methods of measurements for testing and determining the characteristics of electric generators, generator sets, and associated equipment. The illustration and description of the test instruments together with instruction for their use are included as applicable under each method.

## 1.2 Numbering System

The methods are designated by numbers assigned in accordance with the following system:

*1.2.1 Method Numbers*

The methods are divided into two main groups: the 100 numbered series in section 4 covers instruments and measurements; and the 200 numbered series in section 5 covers instrumentation and general test methods. (The method numbers assigned are the same as those formerly used in the uncoordinated document MIL–G–10228 which has been in general use as a reference document for the past several years.)

*1.2.2 Decimal System*

The decimal system is used for the purpose of listing similar or associated methods in numerical sequence and to provide means for readily identifying main and subparagraphs for purpose of reference.

# 2. REFERENCED DOCUMENTS

## 2.1 Specifications and Standards

The following specifications and standards, of the issue in effect on date of invitation for bids, form a part of this handbook.

FEDERAL SPECIFICATION

VV–F–800—Fuel Oil, Diesel.

MILITARY SPECIFICATIONS

MIL–L–2104—Lubricating Oil, Internal Combustion Engine, Heavy Duty.

MIL–G–3056—Gasoline, Automotive, Combat.

MIL—G–5572—Gasoline, Aviation; Grades 80/87, 91/96, 100/130, 115/145.

MIL–L–6082—Lubricating Oil: Aircraft Reciprocating (Piston) Engine.

MIL–L–9000—Lubricating Oil, Internal Combustion Engine, Diesel.

MIL–L–10295—Lubricating Oil, Internal Combustion Engine, Sub-Zero.

MIL–F–16884—Fuel Oil, Diesel (Marine).

FEDERAL AND MILITARY STANDARDS

Fed Test Method Std No. 791—Lubricants, Liquid Fuels, and Related Products; Methods of Testing.

MIL–STD–705—Generator Sets, Engine-Driven Methods of Tests and Instructions.

(Copies of specifications and standards required by contractors in connection with specific procurement functions should be obtained from the procuring activity or as directed by the contracting officer.)

## 2.2 Other Publications

The following publications of the issue in effect on date of invitation for bids, unless otherwise stated, form a part of this handbook.

AMERICAN STANDARDS ASSOCIATION STANDARDS

C–50 Series—Rotating Electrical Machinery (included as a general reference).

(Applications for copies of American Standards should be addressed to the American Standards Association, 70 East 45th Street, New York 17, N.Y.)

NATIONAL BUREAU OF STANDARDS

Handbook H30—National Electrical Safety Code.

WEATHER BUREAU

Publication 235—Psychrometric Tables for Obtaining the Vapor Pressure, Relative Humidity, and Temperature of the Dew Point.

(Copies of Handbook H30 and Publication 235 may be obtained upon application, acompanied by money order or cash, to the Superintendent of Documents, U.S. Government Printing Office, Washington 25, D.C.)

## 2.3 Textbooks

The following textbooks are listed for information purposes and are not to be considered as a part of this handbook:

Electrical Engineering Laboratory Experiments, Ricker and Tucker, 4th Ed., McGraw-Hill Book Co.

Electrical Measurement, Harris, 1st Ed., John Wiley and Sons.

Electrical Engineers' Handbook, Pender and Del Mar, Vol. 1, 4th Ed., John Wiley and Sons.

Standard Handbook for Electrical Engineers, A. E. Knowlton, 8th Ed., McGraw-Hill Book Co.

Chamber's Technical Dictionary, Tiveney and Hughes, Rev. Ed., The MacMillan Co.

*Note.* When Government drawings, specifications, standards, or other data are used for any purpose other than in connection with a definitely related Government procurement operation, the United States Government thereby incurs no responsibility nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, standards, or other data, is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

## 3. DEFINITIONS

*Armature*—The armature is the part of a machine which includes the main current-carrying winding.

In direct-current machines and in alternating-current commutator machines, the armature winding is connected to the commutator and the armature is the rotating member.

In alternating-current machines without commutators the armature may be either the rotating member or the stationary member.

*Bridge circuit*—A bridge circuit is a network which is so arranged that, when an electromotive force is present in one branch, the response of a suitable detecting device in another branch may be made zero by a suitable adjustment of the electrical constants of still other branches; and which is characterized by the fact that, if the electromotive force and the detecting device are interchanged after completing an adjustment, the response of the detecting device is still zero.

*Brush*—A brush is a conductor serving to maintain electric contact between stationary and moving parts of a machine or other apparatus.

*Circuit interrupter*—A circuit interrupter is a device for interrupting a circuit between separable contacts under normal or abnormal conditions.

*Collector rings*—Collector rings are metal rings suitably mounted on an electric machine serving, through stationary brushes bearing thereon, to conduct current into or out of the rotating member.

*Commutator*—A commutator is a cylindrical ring or disk assembly of conducting members, individually insulated in a supporting structure with an exposed surface for contact with current-collecting brushes and ready for mounting on an armature shaft, quill or spider.

*Contact resistance*—Contact resistance is the electrical resistance between wires, a wire and terminal, or a wire and anything it is connected to.

*Contactor*—A contactor is a device, operated other than by hand, for repeatedly establishing and interrupting an electric power circuit.

*Contacts, electrical*—Electrical contacts are conducting parts which contact to complete or to interrupt a circuit.

*Current transformer*—A current transformer is a transformer intended for measurement or control purposes, designed to have its primary winding connected in series with an ac circuit carrying the current to be measured or controlled.

*Damping factor*—The damping factor of an instrument is the ratio of the deviations of the pointer from the position of equilibrium in two consecutive swings, the greater deviation being divided by the lesser.

*Delta connection*—A delta connection is three windings so connected that the resultant wiring diagram is triangular in shape, with terminals at the corners.

*Dynamometer-type instrument*—An electrodynamometer instrument is an instrument which depends for its operation on the reaction between the current in one or more moving coils, and the current in one or more fixed coils.

*Electrical degree*—An electrical degree is the 360th part of the angle subtended, at the axis of a machine, by two consecutive field poles of like polarity. One mechanical degree is thus equal to as many electrical degrees as there are pairs of poles in the machine.

*Electrostatics*—Electrostatics is that branch of science which deals with the laws of electricity at rest.

*Electrostatic instrument*—An electrostatic instrument is an instrument which depends for its operation on the forces of attraction or repulsion between bodies charged with electricity.

*Electronics*—Electronics is that branch of science and technology which relates to the conduction of electricity through gases or in vacuo.

*Emf (electromotive force)*—Electromotive force is the property of a physical device which tends to make an electric current flow. The practical unit is the volt.

*Exciter*—An exciter is an auxiliary generator which supplies energy for the field excitation of another electric machine.

*Exciter response*—Exciter response is the rate of increase or decrease of main exciter voltage when resistance is suddenly removed or inserted in the main exciter field circuit.

*Three-phase four-wire system*—A three-phase four-wire system is a system of alternating-current supply comprising four conductors, three of which are connected as in a three-phase three-wire system, the fourth being connected to the neutral point of the supply, which may be grounded.

*Harmonic*—A harmonic is a component of a periodic quantity which is an integral multiple of the fundamental frequency. For example, a component the frequency of which is twice the fundamental frequency is called the second harmonic.

*Hysteresis, magnetic*—Magnetic hysteresis is the property of a magnetic material by virtue of which the magnetic induction for a given magnetizing force depends upon the previous conditions of magnetization.

*Milliampere*—A milliampere is one one-thousandth of an ampere.

*Millivolt*—A millivolt is one one-thousandth of a volt.

*Multiplier, instrument*—An instrument multiplier is a particular type of series resistor which is used to extend the voltage range of an instrument beyond some particular value for which the instrument is already complete.

*Potential, electric*—The electric potential of a point is the potential difference between the point and some equipotential surface, usually the surface of the earth, which is arbitrarily chosen as having zero potential. A point which has a higher potential than zero surface is said to have a positive potential; one having a lower potential has a negative potential.

*Potential transformer*—A potential (voltage) transformer is a transformer intended for measurement or control purposes which is designed to have its primary winding connected in parallel with an ac circuit, the voltage of which is to be measured or controlled.

*Power factor*—Power factor is the ratio of active power (kw) to apparent power (kva).

*Quadrature*—Quadrature expresses the phase relationship between two or more periodic quantities of the same period when the phase difference between them is one-fourth of a period.

*Rated burden*—The rated burden of an instrument transformer defines a burden which can be carried at a specified accuracy for an unlimited period without causing the established limitations to be exceeded.

*Rectifier*—A rectifier is a device which converts alternating current into unidirectional current by virtue of a characteristic permitting appreciable flow of current in only one direction.

*Resistance*—Resistance is the (scalar) property of an electric circuit or of any body that may be used as part of an electric circuit which determines for a given current the rate at which electric energy is converted into heat or radiant energy and which has a value such that the product of the resistance and the square of the current gives the rate of conversion of energy.

*Resistive load*—Resistive load is an electrical load in which energy is dissipated with the ac voltage and current in exact time phase.

*Rms (root mean square)*—Root mean square is the square root of the average of the squared instantaneous values taken over one complete cycle of a repetitively varying quantity.

*Selector switch*—A selector switch is a form of air switch arranged so that a conductor may be connected to any one of several other conductors.

*Short circuit*—A short circuit is an abnormal connection of relatively low resistance, whether made accidentally or intentionally, between two points of different potential in a circuit.

*Shunt, instrument*—An instrument shunt is a particular type of resistor designed to be connected in parallel with the measuring device to extend the current range beyond some particular value for which the instrument is already complete.

*Single-phase circuit*—A single-phase circuit is either an alternating-current circuit which has only two points of entry or one which, having more than two points of entry, is intended to be so energized that the potential differences between all pairs of points of entry are either in phase or differ in phase by 180°.

*Sinusoidal voltage*—A simple sinusoidal voltage is a symmetrical alternating voltage, the instantaneous values of which are equal to the product

of a constant, and the sine or cosine of an angle having values varying linearly with time.

*Stator*—The stator is the portion of a machine which contains the stationary parts of the magnetic circuit with their associated windings.

*Three-phase circuit*—A three-phase circuit is a combination of circuits energized by alternating electromotive forces which differ in phase by one-third of a cycle, i.e., 120°.

*Transient surge*—A surge in an electric circuit is the transient variation in the current or potential at a point in the circuit.

*Waveform*—The shape of the curve resulting from a plot of instantaneous values of voltage or current against time as abscissa is its waveform or waveshape.

*Wye*—A wye connection is three windings, the similar ends of each connected to a common point (the neutral) and the other ends of each forming the three line terminals.

*Zero adjuster*—A zero adjuster is a device for bringing the pointer of an electric instrument to zero when the electrical quantity is zero.

# 4. INSTRUMENTS AND MEASUREMENTS 100 SERIES

# METHOD 101.1

# MEASUREMENT OF POTENTIAL

## 101.1.1 General

The primary standard of voltage, electromotive force, or potential, adopted January 1, 1948, is the ABSOLUTE VOLT. It is related to the previous standard, the INTERNATIONAL VOLT, as follows:

1 absolute volt = 0.99967 international volt

1 international volt = 1.00033 absolute volts

For practical purposes, the difference of about 0.03 percent between the two standards is negligible. The absolute volt is represented by the unvarying electromotive force (emf), which, if applied to a conductor having a resistance of one absolute ohm, will produce a current of one absolute ampere. Although obviously intended to be a derived standard, the constancy and reproducibility of the standard saturated emf cell is such that emf has superseded current as a basic standard. Thus, the primary standards of voltage in the national Bureau of Standards at Washington are in the form of standard-type emf cells, which are kept at constant temperature.

## 101.1.2 Potentiometers

To intercompare standard cells, or to compare an emf directly with the standard, a precision potentiometer (fig. 101.1–I) is used. This instrument consists of an adjustable source of direct current, a series resistance equipped with a calibrated, adjustable tap, and a sensitive galvanometer.

The emf to be measured is compared with the emf tapped from the potentiometer resistor through the galvanometer.

When the galvanometer indicates zero current, the potentiometer voltage, as indicated on the calibrated tap, is equal to the emf being measured.

The potentiometer is standardized by choosing a tap-setting equal to the voltage of a standard cell, and then adjusting the potentiometer current until the instrument is balanced. This operation should be performed every hour if the instrument is in continuous use and before each reading if the instrument issued intermittently.

Because the potentiometer is a null-balance instrument, it draws no current from the circuit being measured and so finds its maximum usefulness in the measurement of emf's of standard cells, and other high impedance circuits.

## 101.1.3 Indicating Voltmeters

### *101.1.3.1 Dc Voltage*

For the measurement of direct voltage, D'Arsonval-type voltmeters are used (fig. 101.1–II). They may be obtained with voltage ranges up to 750 volts full scale, self-contained, and up to 50,000

*Figure 101.1–I. Potentiometer.*

*Figure 101.1–II. Dynamometer-type dc voltmeters.*

volts by means of an external multiplier (fig. 101.1–III). They also are available as low-resistance millivoltmeters having full scale readings from 6 millivolts up.

These voltmeters, especially millivoltmeters, should not be connected into circuits having voltages higher than the rating of the instrument. To measure voltages higher than the rating of the instrument, a multiplier (series resistance) must be

*Figure 101.1–III. Series resistance multiplier.*

used with it (fig. 101.1–III). In this case, the correct voltage is obtained by solving the following equation:

$$E = \frac{V_r(R_v + R_m)}{R_v}$$

where:

$E$ is the voltage to be measured.

$V_r$ is the reading of the voltmeter.

$R_v$ is the resistance of the voltmeter (this may be found on the voltmeter dial or on the voltmeter cover).

$R_m$ is the resistance of the series multiplier (this value may be found on the series multiplier case). This formula, solved for $R_m$, can be used for selecting series multiplier to be used if approximate value of $E$ is known.

Another method of measuring high dc voltage is to place two voltmeters in series and take simultaneous readings of both instruments. The sum of the two readings is the voltage.

Because of the high-inductive-voltage surge which may bend the pointer, dc voltmeters should be disconnected from a field circuit before the field switch is opened. Because of high alternating voltages developed by transformer action in the field windings during starting, dc voltmeters also should be disconnected from synchronous motor or synchronous condenser fields before the machines are started from the ac side.

*101.1.3.2 Ac Voltage*

Dynamometer-type voltmeters (fig. 101.1–IV) are used to measure alternating voltage. Their ranges usually are from 7½ to 750 volts full scale.

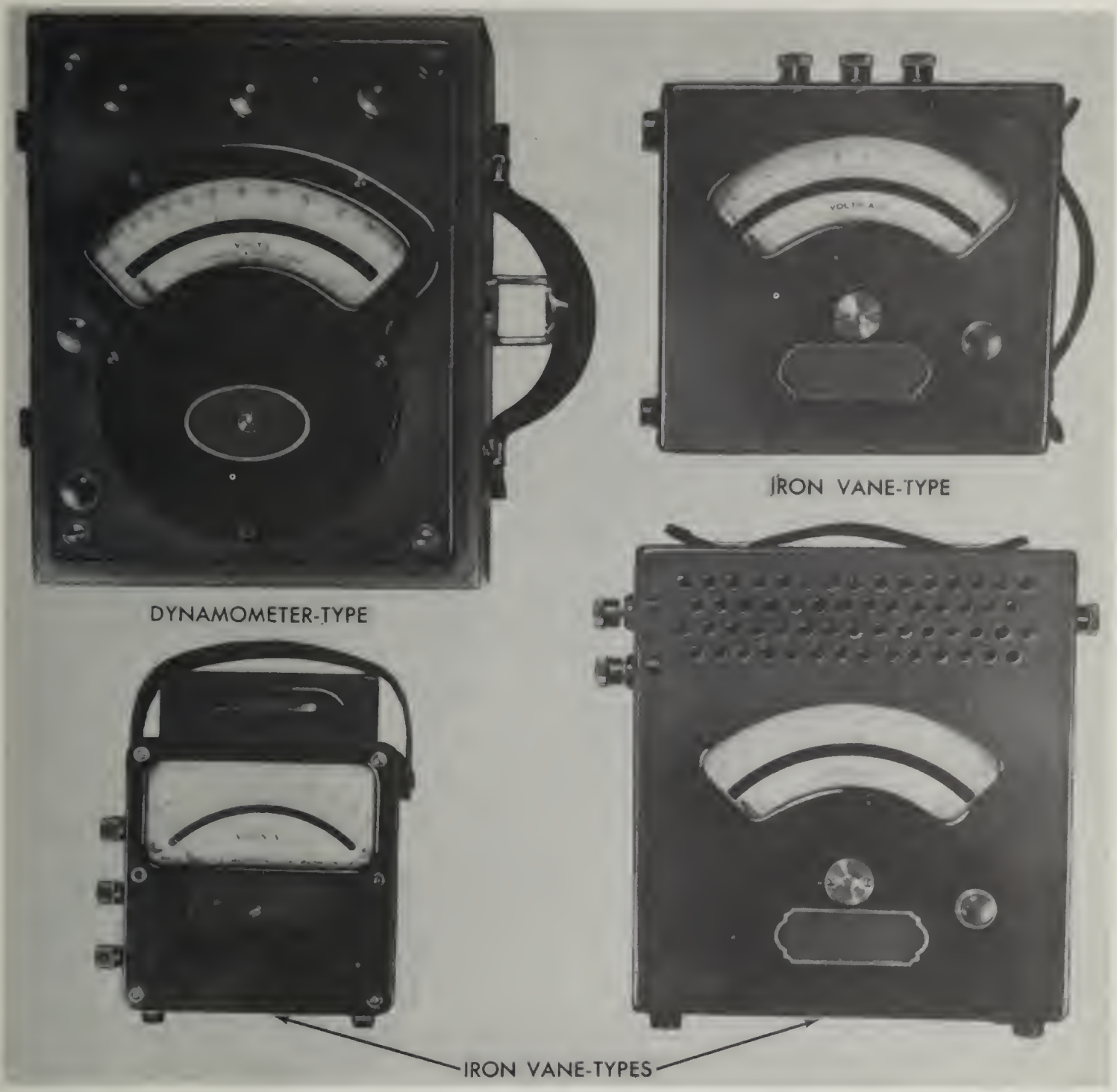


*Figure 101.1–IV. Representative types of ac voltmeters.*

These voltmeters also may be used on direct voltage without appreciable error if averaged direct and reverse readings are taken. However, they cannot be used with accuracy as low on the scale as the corresponding dc voltmeters because their scales normally are constricted in this region.

Dynamometer-type voltmeters should not be used with frequencies of more than 133 cycles per second unless specifically indicated otherwise on the instrument.

Other types of ac voltmeters include the "iron vane" type, shown in figure 101.1–IV; vacuum tube voltmeters, shown in figure 101.1–V; and electrostatic voltmeters, shown in figure 101.1–VI.

Vacuum tube, or electronic, voltmeters are used to measure approximate voltages. The average value is determined, but the rms value (average time 1.11) is marked on the scale.

Vacuum tube, or electronic, voltmeters are also designed to measure *peak* voltages, which are normally calibrated in rms values, for use at normal scale ranges.

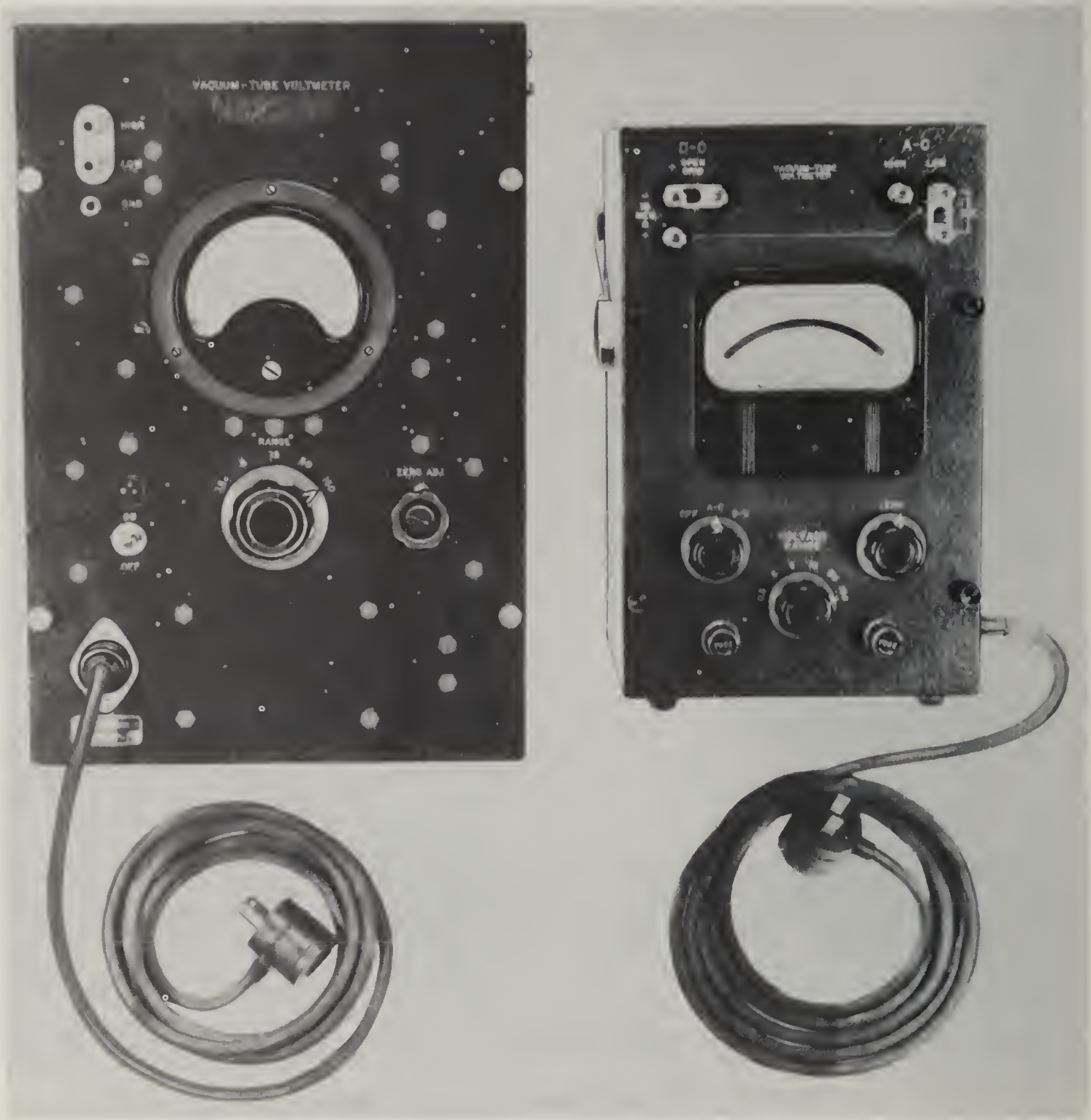


*Figure 101.1–V. Representative vacuum tube voltmeter.*

Electrostatic voltmeters are used to measure the voltage in grounded ac circuits up to 75,000 volts. In this device the voltmeter current is negligible. These voltmeters are of the light-beam type and can be checked with potential or other transformers of known ratio.

Also available are "rectifier" voltmeters, which are practically independent of frequency up to 2,000 cycles, and "crest", or "peak" voltmeters for measurements up to 30,000 volts.

### 101.1.4 Recording Voltmeters

Recording voltmeters (fig. 101.1–VII) normally are available in the same sizes and types as the indicating instruments described above. Recording instruments always must be calibrated on the chart

*Figure 101.1–VI. Representative electrostatic 30-kv voltmeter.*

paper, and readings never should be taken from the indicating pointer which usually is supplied with such instruments.

Recording instruments must be used with the lightest pen pressure and slowest chart speed which will give the desired results.

When recording instruments are used to measure transient or time-varying voltages, the damping setting and chart speed always must be recorded with the data.

An acceptable type of recording voltmeter is shown in figure 101.1–VII. This type of instrument, or equal, will be used throughout the generator tests given in MIL–STD–705. The instrument illustrated is Esterline-Angus, Model AW, adjusted to a damping factor of 3. The recording speed will be specified in the individual tests.

### 101.1.5 Potential Transformers

Potential transformers (fig. 101.1–VIII) are

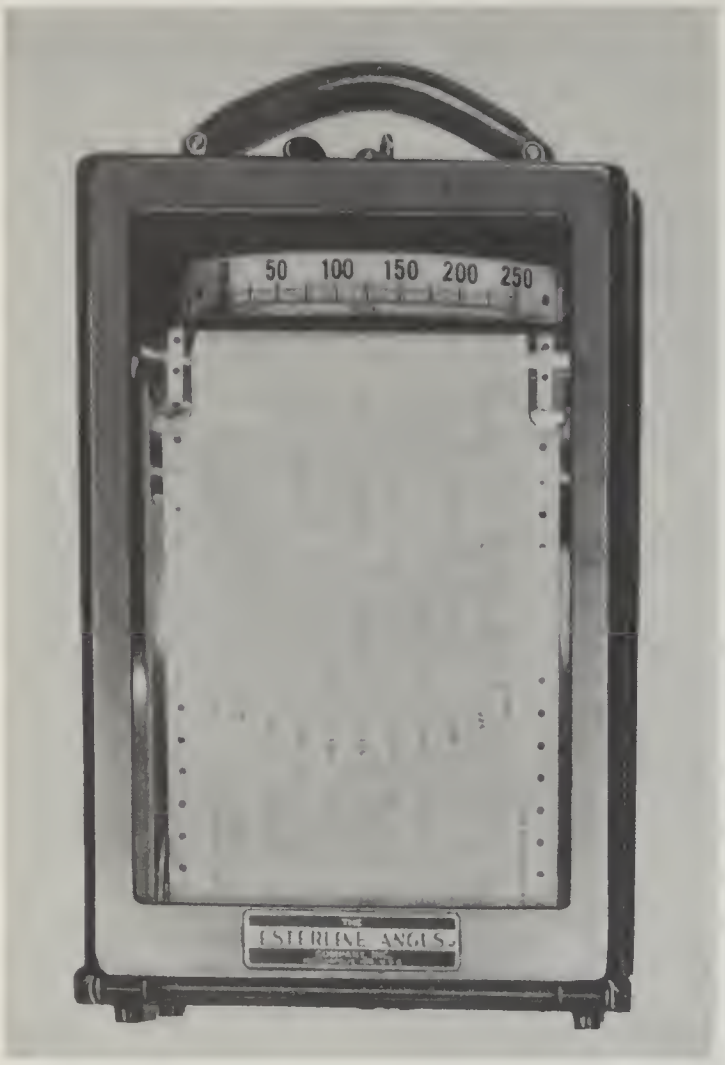


*Figure 101.1–VII. Acceptable type of recording voltmeter.*

used for two purposes: to isolate the testing instruments from the line voltage, and to act as multipliers for the instruments.

To obtain satisfactory accuracy when using a potential transformer, check it under conditions of voltage, frequency, and volt-amphere burden that correspond to the conditions under which it will be used. Temporary departures of circuit values from transformer ratings should not exceed these limits: voltage, 125 percent; frequency 90 percent of lowest or 250 percent of highest rating, at rated voltage; secondary output, 125 percent at rated voltage.

*Figure 101.1–VIII. Potential transformer.*

Two potential transformers and three voltmeters may be used to measure the three line-to-line voltages on three-phase, three-wire circuits. The transformers are connected in open delta. For three-phase, four-wire circuits, three potential transformers connected wye-wye are used. The primary neutral is connected to the system neutral, and the secondary neutral is grounded. The wye-wye connection, with either isolated or grounded primary neutral, must not be used for three-phase, three-wire circuits because of the resulting third harmonics in the three line-to-neutral transformer voltages.

Wye-delta and delta-delta connections also are to be avoided since circulating currents in the closed delta may cause the accuracy to become indeterminate.

# METHOD 102.1

# MEASUREMENT OF CURRENT

## 102.1.1 General

The primary standard of current is the ABSOLUTE AMPERE which is derived from the fundamental units of length, mass, and time. It is related to the previous standard, the INTERNATIONAL AMPERE, as follows:

1 absolute ampere=
1.000165 international amperes
1 international ampere=
0.999835 absolute ampere

For practical purposes, the difference of about 0.017 percent between the two standards is negligible. Because of the inherent transient nature of current, it is generally unsatisfactory as a primary standard and, therefore, in practice is derived from the absolute ohm and volt. Thus, the primary standards of current are in the form of current carrying manganin resistors or shunts, and standard emf cells. The shunt voltage drop is compared with the cell voltage by means of a precision potentiometer. The current is obtained from the formula $I=\frac{E}{R}$ where $I$ is the current in amperes, $E$ is the potentiometer reading in volts, and $R$ is the resistance in ohms of the shunt used.

## 102.1.2 Indicating Ammeters

*102.1.2.1 Direct Current*

For the measurement of direct current, D'Arsonval-type ammeters are used. These instruments may be obtained with full-scale readings from 20 microamperes up to 30 amperes self contained (fig. 102.1–I).

For currents above 30 amperes, shunts are used in connection with ammeters (fig. 102.1–II). Multiple shunts are sometimes used because of the ease in changing ranges (fig. 102.1–III). When ammeters are used in connection with shunts, the millivolt rating of the instrument should be the same as that of the shunt at full rated current.

*Figure 102.1–1. Self-contained dc ammeter.*

For measuring current beyond the capacity of the instrument at hand, two ammeters may be placed in parallel, but both instruments must be read simultaneously. If two shunts are used in parallel, an ammeter must be connected to each and the readings taken on both simultaneously.

*102.1.2.2. Alternating Current*

For the measurement of alternating currents, dynamometer and iron-vane type instruments (fig. 102.1–IV) normally are used. Their standard ranges are from 200 milliamperes to 200 amperes full scale. Because of the nonlinear characteristics of most ac ammeter scales, they should not be used in the lower portion of their ranges. Ammeters used with current transformers ordinarily are 5-ampere instruments.

## 102.1.3 Recording Ammeters

The same principles apply to the use of recording ammeters (fig. 102.1–V) as were discussed in Method 101.1, under the heading Recording Voltmeters.

*Figure 102.1–II. Dc ammeter with separate shunt.*

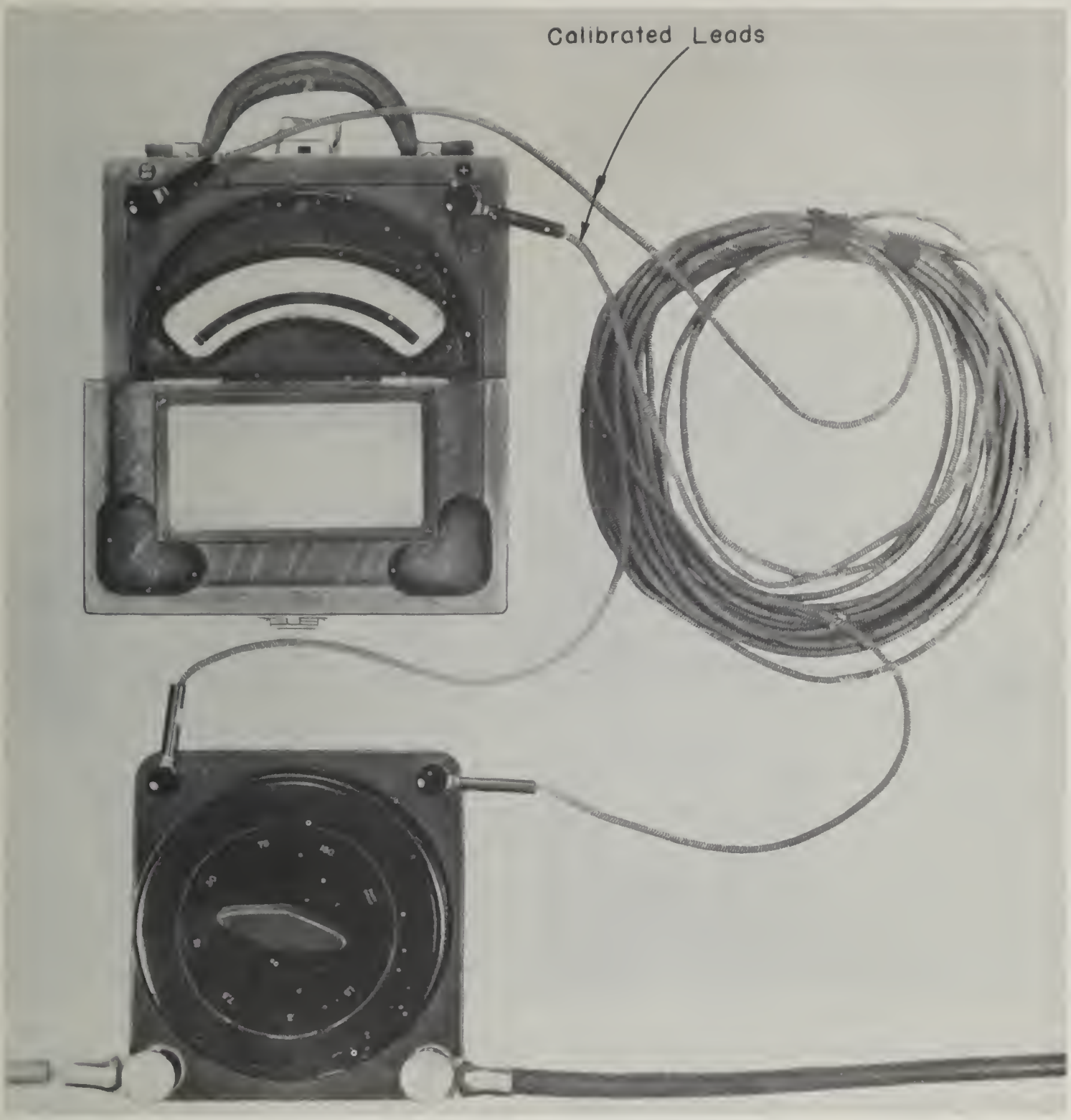


*Figure 102.1–III. Dc ammeter with rotary shunt.*

### 102.1.4 Current Transformers

Current transformers (fig. 102.1–VI) are used for two purposes; to isolate the instrument from the line voltage, and to act as a multiplier for the instruments.

The accuracy of a current transformer is determined by a shunt method in which the drop across a noninductive shunt, connected in series with a transformer primary winding, opposes the drop across another shunt in the secondary circuit through a suitable detector. In order to obtain satisfactory accuracy when using a current transformer, it should be checked under conditions of voltgage, current, and frequency that correspond

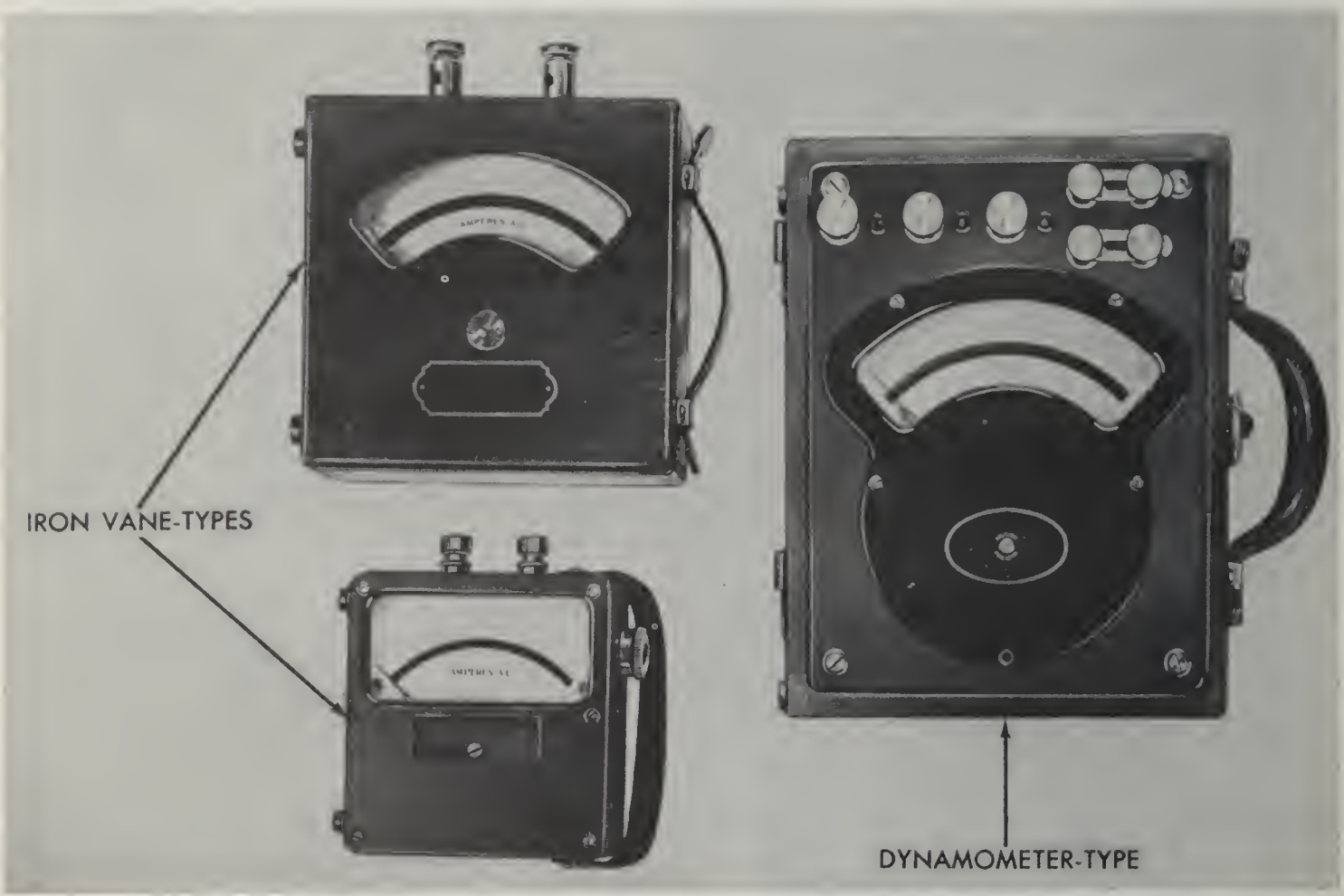


*Figure 102.1–IV. Self-contained ac ammeters.*

*Figure 102.1–V. Acceptable type of recording ammeter.*

to the conditions under which it will be used. In general, this means that the circuit current should range from about 20 to 100 percent of rated current, while the frequency and secondary burden should be nearly the same in both cases. The circuit frequency should not be less than 90 percent of the lowest rated frequency, and the secondary burden should not exceed one ohm. Departures from these specifications should receive special consideration.

Opening the secondary of the current transformer while alternating current is flowing in the primary, or allowing direct current to flow in either winding, may cause the transformer core to become magnetized and impair the accuracy of the instrument. In addition, dangerously high voltages may be induced, causing possible injury to the operator.

When a current transformer becomes accidentally magnetized, it should be demagnetized by applying at least 50 percent of the rated primary alternating current with 30 ohms or more in the secondary circuit. This resistance should then be gradually reduced to zero in steps of one ohm or less. This should be accomplished only by experienced instrument repairmen.

It is desirable to use three current transformers with three ammeters (or one ammeter and a suitable transfer switch) to measure the three line currents on three-phase, three-wire circuits. The use of only two current transformers tends to unbalance the circuit when both voltage and current are small, as when testing small generators. For larger generators, two transformers may be used in open delta.

***Caution:*** **In order to obtain maximum safety for operators and apparatus, one secondary terminal must be grounded; the metal case or core, if accessible, must be grounded; connections must not be made or changed with voltage on; the primary of the transformer must be connected in the line and the secondary to the instruments, and not vice versa: and the secondary of the transformer must not be opened with the current flowing in the primary. A shortening switch across the secondary will be provided. This switch will be opened only when taking meter readings. This switch normally will be a part of the current transformer. Temporary departures of circuit values from transformer ratings must not exceed these limits: (a) voltage, 125 percent, (b) current, 125 percent, (c) frequency, 100 percent of highest rating.**

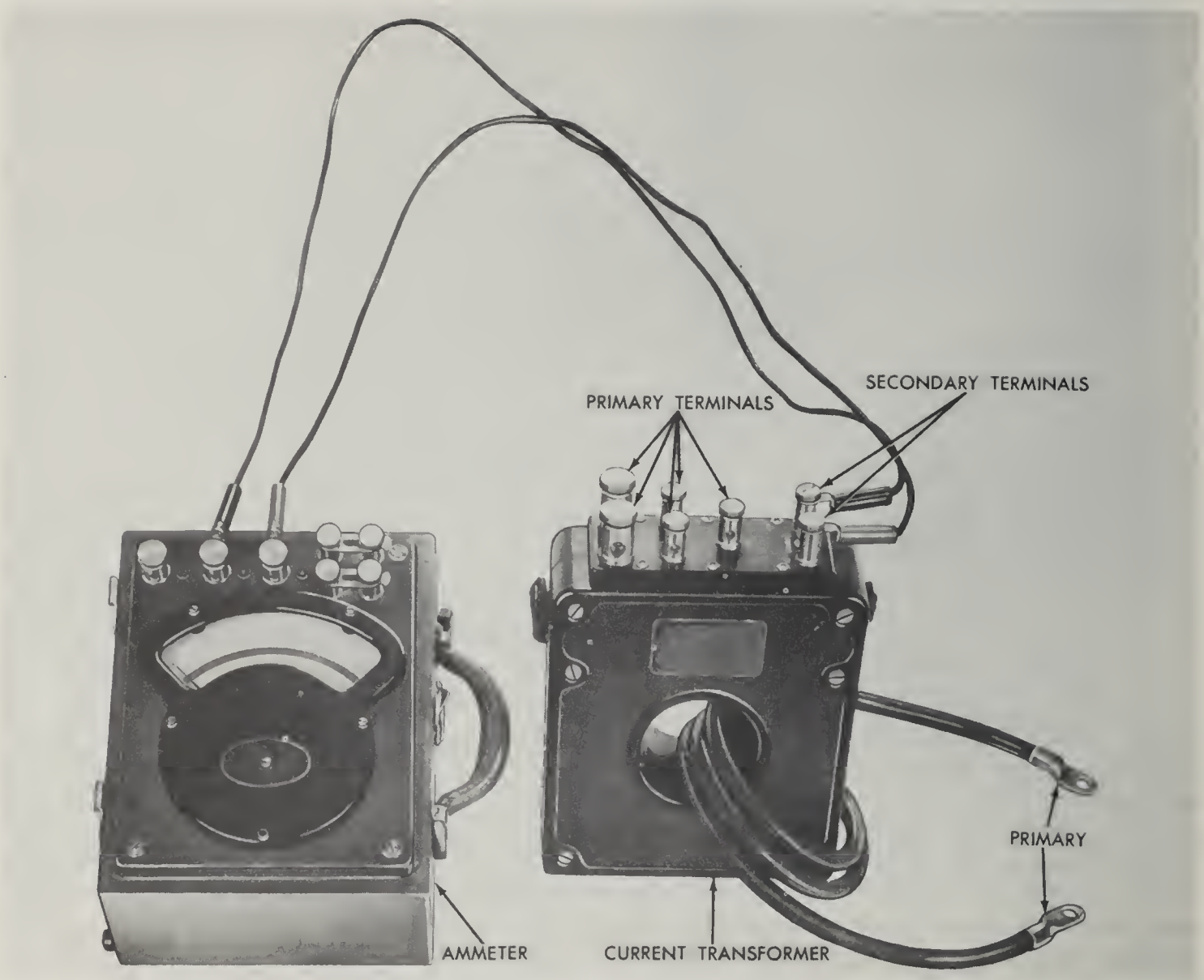


*Figure 102.1—VI. Ac ammeter with current transformer.*

# METHOD 103.1

# MEASUREMENT OF POWER

## 103.1.1 General

Mechanical power most commonly is expressed in horsepower. Electrical power ordinarily is expressed in watts.

Horsepower is the equivalent of the amount of work performed in a given time. One horsepower is the rate of work performed equivalent to raising 33,000 pounds 1 foot in 1 minute.

There is no practical primary standard of electric power, the watt being derived from the volt and the ampere. However, expressed in terms of work performed, one kilowatt (1,000 watts) is equal to 1.341 horsepower.

## 103.1.2 Dc Measurement

Dc power is measured by computing the product of the voltage and amperage in the circuit. This is represented by the formula $W=EI$. Wattmeters ordinarily are not used for measuring power in dc circuits.

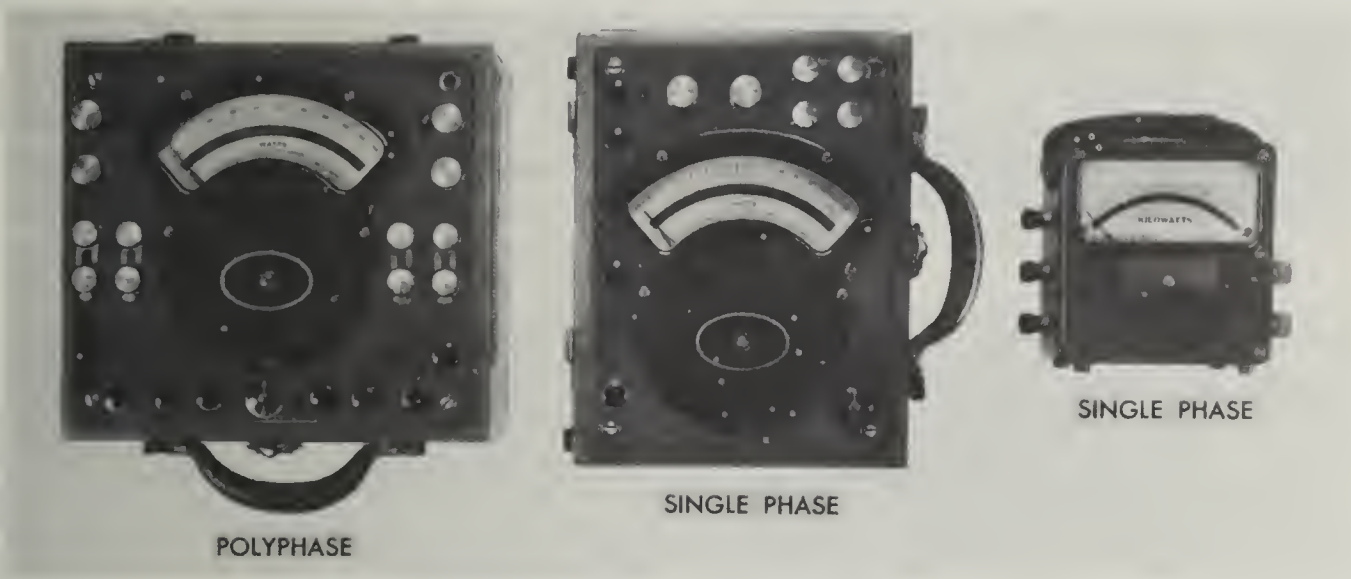


*Figure 103.1–I. Types of wattmeters.*

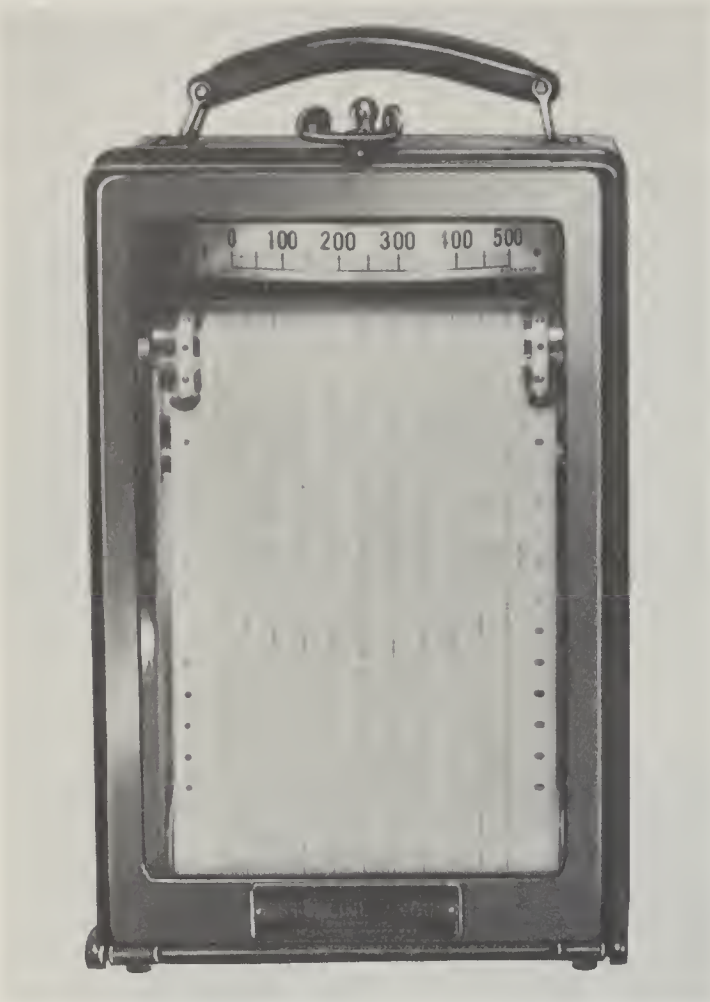


*Figure 103.1–II. Acceptable type of recording wattmeter.*

### 103.1.3 Ac Measurements

Wattmeters (figs. 103.1–I and 103.1–II) for measuring ac power may be designed for use in single-phase circuits or in polyphase systems. The formula for watts in a single-phase circuit is $W=EI\cos\theta$, where $E$ is the line voltage, $I$ is the line current, and $\cos\theta$ is the power factor (see Method 107.1). For balanced three-phase circuits the formula is $W=\sqrt{3}\,EI\cos\theta$, where $E$ is the line-to-line voltage, $I$ is the line current, and $\cos\theta$ is the power factor.

For a further discussion of the formulas for power in ac circuits, see Method 205.1, in which the various hookups of wattmeters in different types of ac circuits are discussed.

Wattmeters generally are available with potential circuits rated from 10 to 600 volts, and current circuits rated from 1.5 amperes to 200 amperes. Full-scale readings for such instruments range from 15 to 120,000 watts. There also are special wattmeters designed for use at low-power factors.

Wattmeters for general use ordinarily are checked by applying controlled direct voltage to the potential circuits, and controlled direct current to the current circuit. The calibration usually is checked at at least one point on the scale at rated cycles, unity, and 0.5 leading and lagging power factors.

# METHOD 104.1

# MEASUREMENT OF FREQUENCY

## 104.1.1 General

Frequency is defined as the number of recurrences of a cyclic quantity per unit of time. For ac circuits, frequency normally is expressed in terms of the number of cycles per second.

The primary standard of frequency is maintained at the National Bureau of Standards in the form of quartz-crystal oscillators maintained under carefully controlled conditions, at constant pressure. The oscillators control various standard frequencies ranging from 440 cycles to 15 megacycles per second. Some of these are broadcast continuously.

## 104.1.2 Indicating Frequency Meters

Indicating frequency meters (fig. 104.1–I) are constructed on the resonant-circuit principle. They usually make use of two or more resonant circuits and a differential-type measuring instrument. Thus, if one circuit resonates at a frequency slightly above the range of the instrument while the other reaches resonance slightly below this range, the ratio of the currents in the two circuits is a measure of the impressed frequency.

Indicating frequency meters of this type have no springs to return the pointer to the end of the scale, therefore, the pointer will take no particular position when the instrument is not connected in a circuit.

These instruments will operate with satisfactory accuracy on voltages within 10 percent of their rating and generally are unaffected by voltage changes within this range.

## 104.1.3 Recording Frequency Meters

The resonant-circuit, differential-current type of instrument described above also is used as a basis for recording frequency meters (fig. 104.1–II).

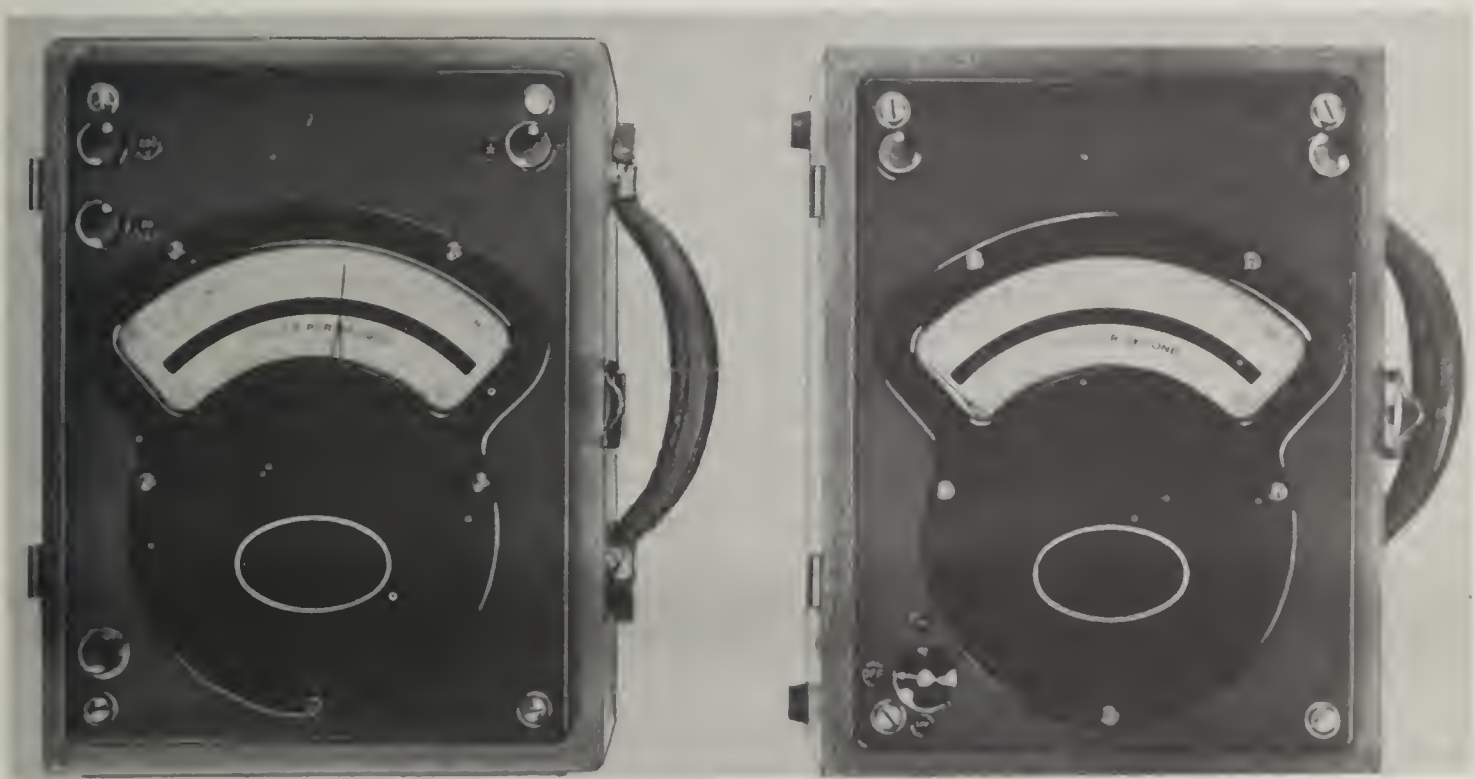

*Figure 104.1–I. Indicating frequency meters.*

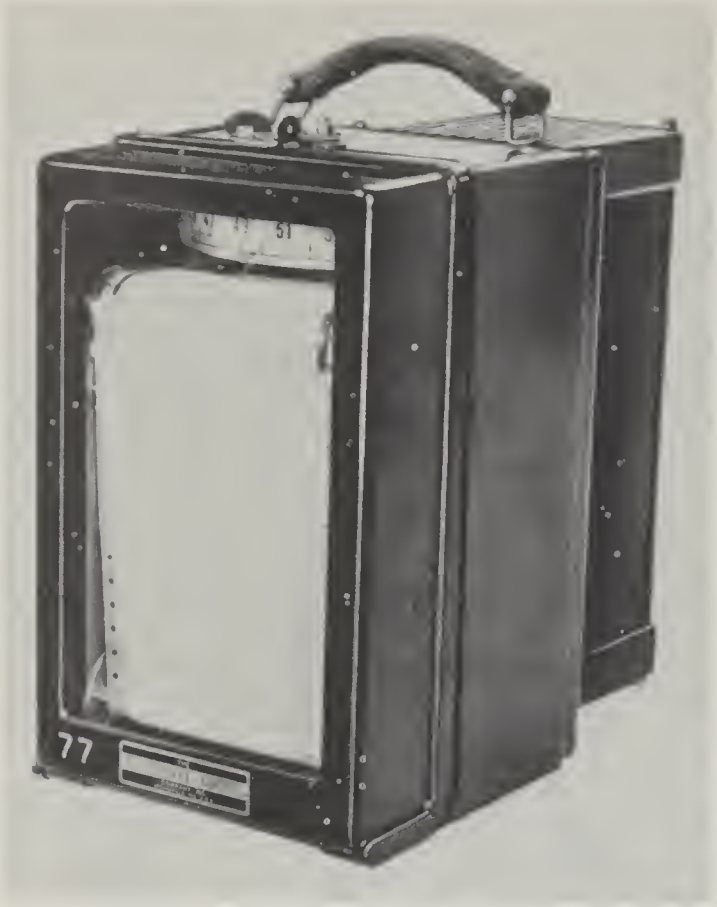

*Figure 104.1–II Acceptable type of recording frequency meter.*

In recording frequency meter, the pointer is replaced by a pen, and provision is made for a strip chart.

In evaluating the performance of an engine-generator set, the transient change in speed of the set due to a sudden change in load is often of considerable interest. One method of measuring this transient phenomenon is by the use of a recording frequency meter. This method is especially convenient for alternating current generators, and has the important advantage of giving a graphical record of frequency variation. However, because of the effects of inertia and damping, the response of the instrument is never instantaneous, consequently the measured frequency variation is subject to dynamic errors which may sometimes be very large. Moreover, because of the differences in construction or adjustment, the torque and response characteristics of different instruments (even of the same make) may be different so that their results are not necessarily comparable. Finally, because the torque and response characteristics of a given instrument may be affected by environmental and operating conditions, it is sometimes difficult even to compare readings from the same instrument.*

It has been recognized that an instrument of satisfactory reproducibility, even though it might not be accurate, would provide a satisfactory arbitrary measure for specification and purchase purposes.*

It has been found that with proper adjustments, the response to pulse and random frequency signals of Esterline-Angus, Mdl AW, 115V, 55 to 65 cps frequency recorders can be made closely the same.† Unless otherwise specified in the procurement documents, this specific model instrument coupled with a fast ac voltage regulator‡ will be used for all tests in MIL–STD–705 which call for this type of instrument. Instrument and regulator will be adjusted in accordance with procedures described in National Bureau of Standards Report #3884.†

The chart speeds will be specified in the specific test methods.

### 104.1.4 Vibration Frequency Meters

Vibration-type frequency meters employ mechanical resonance to obtain a frequency indication. These instruments are rugged and dependable and retain their calibration for long periods of time. They are not affected by small changes in signal voltage. However, this type of instrument ordinarily is not used in performing precision tests because of the difficulty in reading exact frequencies to a close enough accuracy and, in addition, they are almost useless in the measurement of frequency transients.

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*Effects of Environmental Operating Conditions on the Transient Response of an Esterline-Angus model AW Recording Frequency Meter. NBS Report #3160, 5 March 1954.

†Dynamic Calibration of Esterline-Angus Model AW Frequency Recorders. NBS Report #3884, 7 January 1955.

‡A fast Low-level AC Regulator. NBS Report #3615, 12 August 1954.

# METHOD 105.1

# MEASUREMENT OF RESISTANCE

## 105.1.1 General

The importance of accuracy in measuring resistance cannot be overemphasized. These measurements are used to calculate the efficiency of a generator, and to determine the temperature rise of the windings. Both of these are critical factors in design. These measurements also are employed to determine the correctness of the internal connections of the generator, and, at times, to ascertain whether a sample test generator is the same as the production model.

The leads of the winding to be measured must be clean. The terminal lugs should be cleaned with sandpaper to make sure that all foreign matter, paint, varnish, or oxide coating is removed and only bright, bare metal remains exposed for contact with the Kelvin or Wheatstone bridge leads. The bridge leads shall be secured firmly to assure positive contact with the terminal lugs. Care must be taken to compensate for lead resistance to the test instrument if such resistance is of a significant value compared to the resistance being measured (par. 105.1.4.1).

## 105.1.2 Standards

The primary standard of resistance is the ABSOLUTE OHM, which is derived from the fundamental units of length, mass, and time. It is related to the previous standard, the INTERNATIONAL OHM, as follows:

1 absolute ohm = 0.999505 international ohm

1 international ohm = 1.000459 absolute ohms

The difference of about 0.05 percent between the two standards is too small to affect ordinary measurements but is important for standardization purposes. The National Bureau of Standards maintains the primary standards of resistance in the form of 1-ohm manganin resistors, which are kept at constant temperature when in use.

## 105.1.3 Classes of Resistance Measurements

There are three general classes into which resistance measurements are divided. These are: LOW resistances, covering a range below 5 ohms; MEDIUM resistances, covering a range between one and 100,000 ohms; and HIGH resistances, covering a range above 50,000 ohms. These will be discussed in detail in the following paragraphs.

Circuits whose resistance is to be measured often are highly inductive, and damage to the galvanometer or detector may result unless the following precautions are exercised: *Close the battery or supply switch first*, wait a few seconds for the current to build up, then *close the detector switch.* After obtaining the setting or reading, *open the detector switch first*, then *open the supply switch.*

## 105.1.4 Low Resistance Measurements

To measure resistance of less than one ohm, one of the following three methods usually should be used: the Double-Bridge Method, the Drop-in-Potential Method, or the Comparison Method.

*105.1.4.1 Double-Bridge Method*

The so-called "Kelvin Double Bridge" (fig. 105.1–I) is a modification of the "Wheatstone Bridge" and is so arranged that the resistance of the instrument leads and contacts is not included in the measured resistance. It is, therefore, adaptable to the measurement of very small resistances, of which the lead and contact resistance would otherwise form a large and indeterminate part.

The isolation of the contact resistance is achieved by the use of separate pairs of leads for current and potential. Therefore, to secure accurate results, the current and potential leads must be attached separately to the measured resistance (fig. 105.1–I). If they are connected together, the advantage of the double-bridge circuit will be reduced.

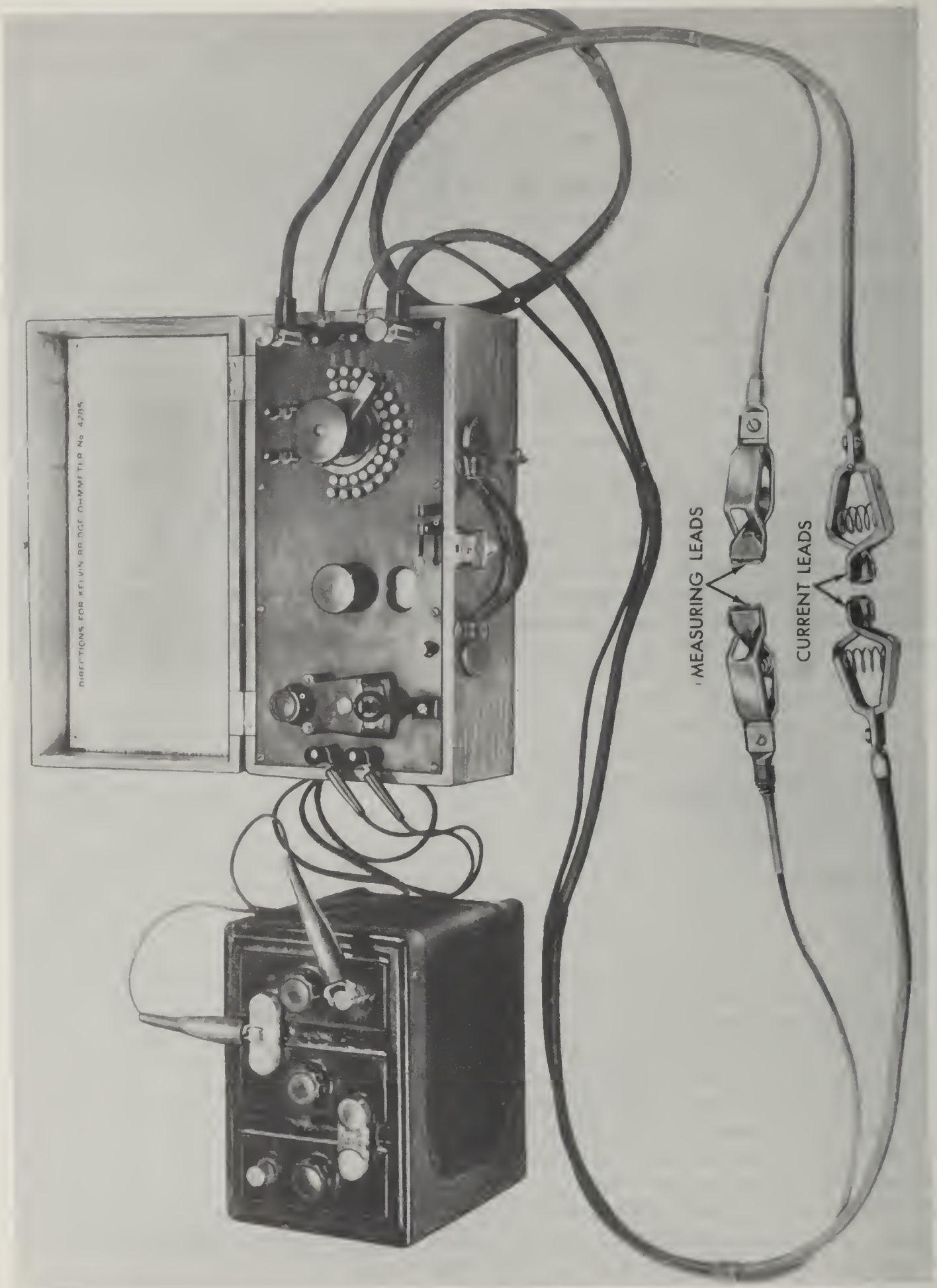



*Figure 105.1–1. Kelvin bridge for measuring low resistance.*

These bridges are supplied with special calibrated leads and, when other leads are used, they should have a resistance within about 20 percent of the resistance of the regular bridge leads.

The double bridge is a null-balance instrument usually containing a ratio dial, a resistance dial, and a galvanometer. Adjust the ratio and resistance dials until the galvanometer indicates balance, then calculate the resistance by multiplying the two dial settings.

When the double bridge is used on inductive circuits, the galvanometer may swing violently when the key is depressed. This is due to the inductive transient and may be ignored. The final, steady position of the galvanometer is the significant indication in all cases.

*105.1.4.2 Drop-in-Potential Method*

A resistance may be calculated by means of Ohm's law, $R=\frac{E}{I}$ if the voltage across the resistance and the amperage through it are known. Thus, to measure a resistance by the drop-in-potential method, connect the unknown resistance in series with an ammeter and a source of constant direct current. Connect a voltmeter across the resistance. Then, calculate the resistance by dividing the voltmeter reading by the ammeter reading (fig. 105.1–II).

The ammeter and voltmeter should be chosen so that the deflections obtained are reasonably large in order to avoid the large percentage errors which may occur in the lower part of the instrument scales.

The current used should be great enough to give good instrument readings without heating the unknown resistance, which would change its value. If the current used is unsteady, simultaneous instrument readings should be taken by two observers. A series of such readings, when averaged, will give reasonably accurate results although the individual readings are in error.

The ratio of the voltmeter resistance to the unknown resistance affects the accuracy of the measurement because the voltmeter current flows through the ammeter. The fractional error is equal to the reciprocal of this ratio (the unknown resistance divided by the voltmeter resistance). If the ratio is 1,000 or less, the ammeter reading should be corrected accordingly.

For very precise work, the voltmeter should be replaced with a potentiometer, and the ammeter with a potentiometer and calibrated shunt.

*105.1.4.3 Comparison Method*

The comparison method of measuring resistance is an adaptation of the drop-in-potential method described above. However, the results obtained are independent of the current measurement.

In this method, connect the unknown resistance in series with a known resistance and a source of direct current (fig. 105.1–III). Measure the voltage across both resistances and calculate the unknown resistance by the following formula:

$$X=\frac{R\ E_x}{E_r}$$

where:

$X$ is the known resistance
$E_x$ is the voltage across $X$
$E_r$ is the voltage across $R$
$R$ is the known resistance

Maximum accuracy is obtained when $R$ and $X$ are equal.

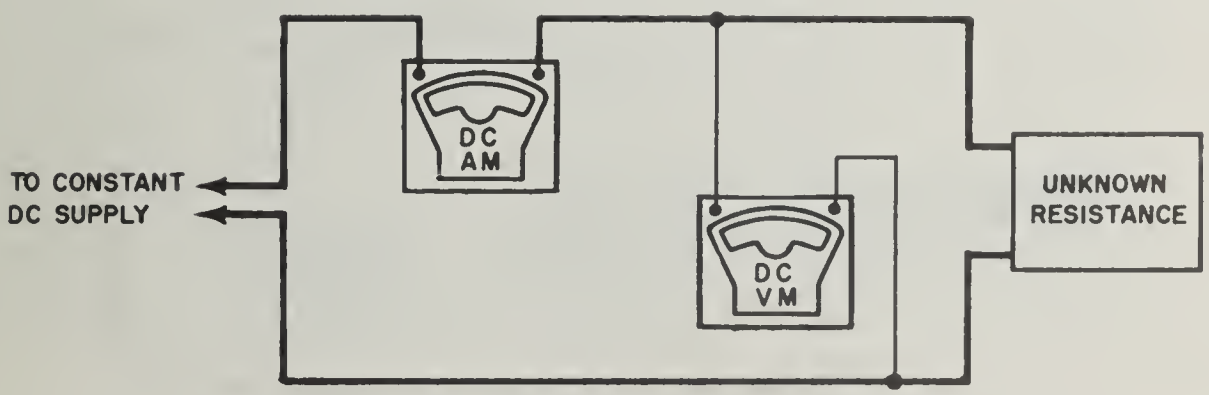



*Figure 105.1–II. Drop-in-potential test connections.*

The current source should be steady and the voltmeter should have a resistance 100 or more times the resistance of either $R$ or $X$.

This method is especially applicable to a wide variety of measurements in which the actual value of each of a series of resistances is relatively unimportant, but in which all of the elements should be equal, such as the windings of a dc generator, or the field coils of an alternator. In this case, connect the elements to be measured in series and measure the drop across each one. If the resistance of one element is used as a standard, the calculations are the same as previously described.

### 105.1.5 Medium Resistance Measurements

Resistances which fall between approximately one ohm and 100,000 ohms are measured by either the "Wheatstone Bridge Method" or with an ohmmeter.

*105.1.5.1 Wheatstone Bridge.*

When the wheatstone bridge (fig. 105.1–IV) is used, ratios should be selected so that the bridge resistances correspond as closely as possible to the resistance being measured.

So that the galvanometer will not be subjected to an inductive voltage surge, use the instrument shunt key to complete the current circuit before the galvanometer circuit is closed. Reverse the sequence as the circuit is opened.

The bridge measures total resistance of the circuit between its binding posts; that is, resistance of the leads (or probes) connecting the bridge with the winding is included with the resistance of the winding itself.

Resistance of the winding is the difference between resistance as measured and resistance of connecting leads, assuming that connections between leads and windings have been properly made. If not, contact resistance also influences the measurement (see par. 105.1.1).

For wheatstone bridges, unless they are self-contained, a current-limiting resistor of about 50 ohms per volt of battery supply should be connected in series with the battery to protect the bridge coils from damage at low resistance settings.

For ordinary bridge measurements, the temperature coefficient of the bridge itself can be neglected. The temperature coefficient of the material being measured, however, must always be considered, and an allowance for it should be made, when necessary, to assure accuracy.

*105.1.5.2 Ohmmeter*

Ohmmeters are available with full-scale ratings from one ohm to 1,000,000 ohms. They are applicable where portability and automatic readings are important factors, but where highly accurate readings are required, the methods described above should be employed.

### 105.1.6 High Resistance Measurements

Resistances of 50,000 ohms and more may be measured by either of the following methods:

*105.1.6.1 Dc Voltmeter Method*

A dc voltmeter with a resistance of approximately 100 ohms per volt, and a source of constant potential, usually about 500 volts, are employed in this method.

Connect the voltmeter directly across the source and note the reading. Insert the unknown resistance in series with the voltmeter and source and again note the reading.

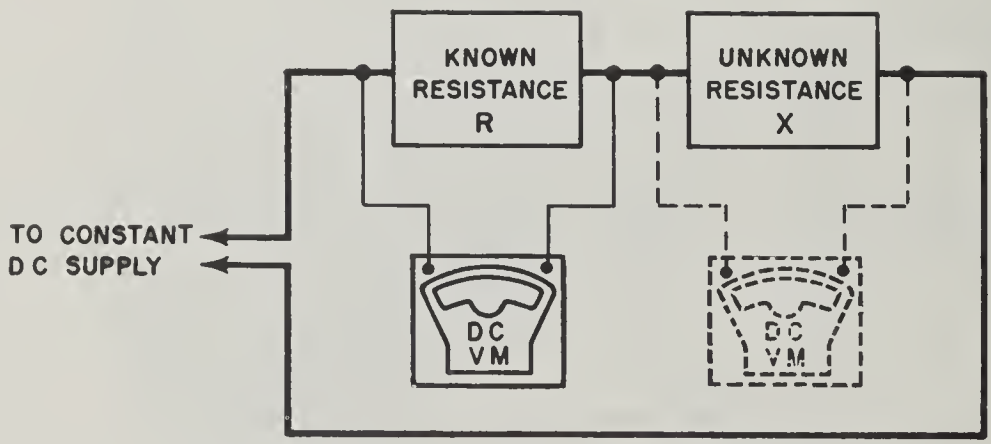



*Figure 105.1–III. Comparison method test connections.*

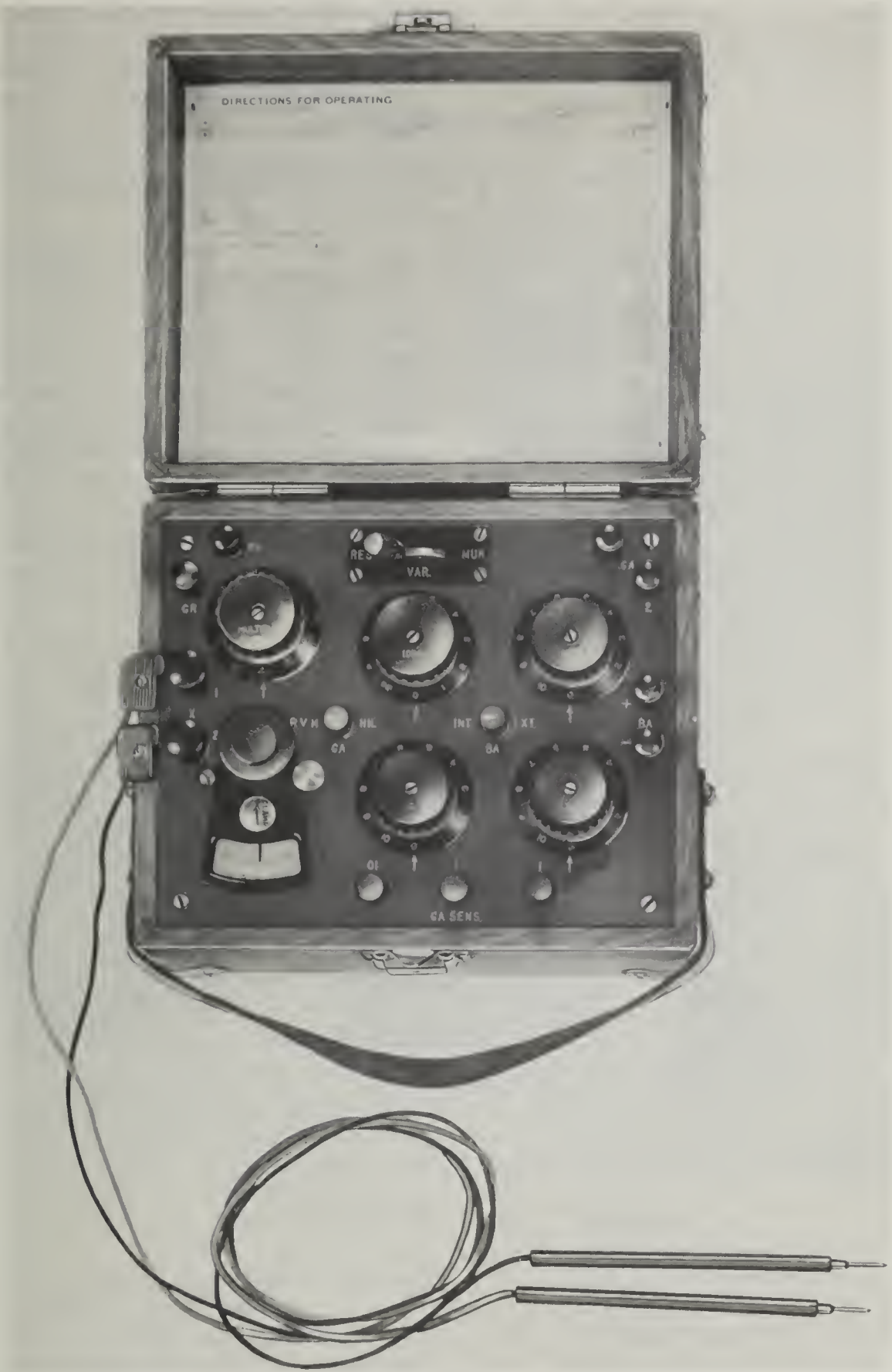



*Figure 105.1–IV. Wheatstone bridge for measuring resistances.*

Calculate the unknown resistance from the following formula:

$$X = R_v \left( \frac{E - V_r}{V_r} \right)$$

where:

$X$ is the unknown resistance
$E$ is the supply voltage
$V_r$ is the voltmeter reading in series with $X$
$R_v$ is the voltmeter resistance

This method should be used only when the supply voltage is steady. When the voltage is unsteady, simultaneous readings of $E$ and $V_r$ should be taken with two voltmeters. In this case, $R_v$ is the resistance of the voltmeter in series with $X$.

Caution must be exercised in the use of this method because of the high voltage supply.

*105.1.6.2 Megger Method*

The so-called MEGGER, or insulation resistance tester, is a self-contained direct-reading instrument, consisting of a small magnetic generator or electronic power supply, standard resistances, and a differential-current milliammeter.

The electromotive force of the generator is impressed upon the unknown resistance and the standard resistance, in parallel. The two currents are compared in the differential-type instrument so that the instrument reading depends only upon the value of the unknown resistance and is independent of the applied emf.

A slip-clutch is used to obtain constant speed on the hand-driven type instruments (fig. 105.1–V) in order to avoid the erratic effects which would otherwise appear as a result of the charging currents caused by variable voltage being applied to circuits having appreciable electrostatic capacity, such as the armatures of large generators. While these instruments are being used, the crank must be turned at a speed sufficiently high to keep the clutch slipping.

The megger always should be operated until the indication is steady and constant before a reading is taken.

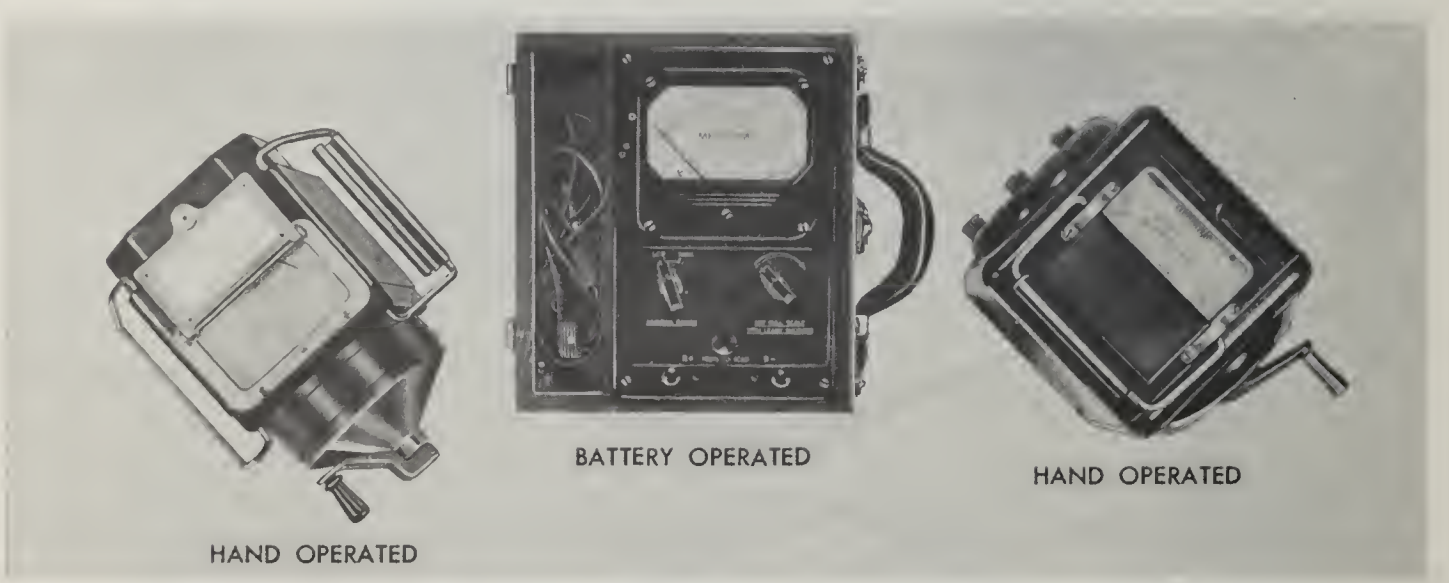



*Figure 105.1–V. Acceptable types of megohm meters.*

# METHOD 106.1

# MEASUREMENTS OF TRANSIENTS AND WAVEFORM

## 106.1.1 General

Electrical transients and waveform may be observed by connecting an oscilloscope or an oscillograph to the circuit in question. Waveform cannot be determined by using a harmonic analyzer to measure the magnitude, or relative value, of the component frequencies, and plotting the waveform from these values, since the phase angle differences of the various harmonics would not be known. However, harmonic analyzers may be used to determine a measure of deviation of an unknown wave from a sine wave.

## 106.1.2 Oscilloscope

Oscilloscopes are extremely versatile instruments which are procurable in single-beam and dual-beam models. The dual-beam model is, in reality, two single-beam oscilloscopes within the same case, using one cathode ray tube to show images from both units simultaneously.

The single-beam oscilloscope (fig. 106.1–I) is used for the observation of waveform and transients, by connecting the signal under observation to the Y, or vertical-axis, input terminals. The internal sweep, which supplies a sawtooth signal with a magnitude linearly proportional to time, is then applied to the X, or horizontal-axis, input terminals and synchronized to the signal being studied. The resulting screen image shows the waveform of the unknown signal as time progresses.

A camera attachment may be used to obtain a permanent record of waveform on photosensitive paper or film.

The following precautions should be observed when using a cathode ray oscilloscope:

(1) Due to the high voltage hazard, the equipment should not be operated with the case removed.

(2) A small spot or highly intensified line should not be kept stationary on the screen since such spots or lines will cause the screen to burn or become discolored.

(3) To preclude spurious deflections, the instrument should be kept as far as possible from magnets, power transformers, reactors, or busses carrying current.

(4) If extremely large power line voltage fluctuations are present, it may be necessary to employ a regulated power supply. However, precautions against spurious magnetic fields should be observed ((3) above).

(5) The image must be kept on the plane portion of the screen. If the image is extended to the edge of the screen, it will be distorted, due to the curvature of the tube. Moreover, the linearity of the oscilloscope amplifier is seldom satisfactory when the signal is amplified to the value necessary for full screen projection.

*Figure 106.1–I. Typical oscilloscope.*

### 106.1.3 Oscillograph

The most common oscillograph (fig. 106.1–II) utilizes the bifilar galvanometer. This galvanometer has a small mirror cemented to two narrow silver ribbons situated in a magnetic field so that a signal current flowing through the ribbons will cause a light beam reflected from the mirror to be deflected a distance proportional to the current.

A galvanometer is very sensitive and, therefore, some means of controlling the applied potential or current must be provided. These controls consist of multipliers and shunts, respectively, which may be a built-in panel type or an auxiliary item which must be used in conjunction with the galvanometer.

To obtain a waveform, the signal is applied to the potential control, or current control, which is then adjusted to get the desired deflection of the light beam. The deflection may be observed on a ground glass screen or simultaneously transferred through an optical system to photosensitive paper or film to obtain a permanent record.

The following precautions should be observed when using the oscillograph:

(1) All leads connecting the circuit to be tested should be well insulated and should be the twisted double conductor type to avoid inductive effects.
(2) The oscillograph should be protected against mechanical vibration at all times, but especially during operation.
(3) A fuse suitable for the galvanometer being employed should be used.
(4) Whenever possible, it is desirable to have one lead at or near ground potential. This should be the unfused lead.
(5) All circuit connections should be made up tightly.
(6) The light beam should be checked for proper width and focus.

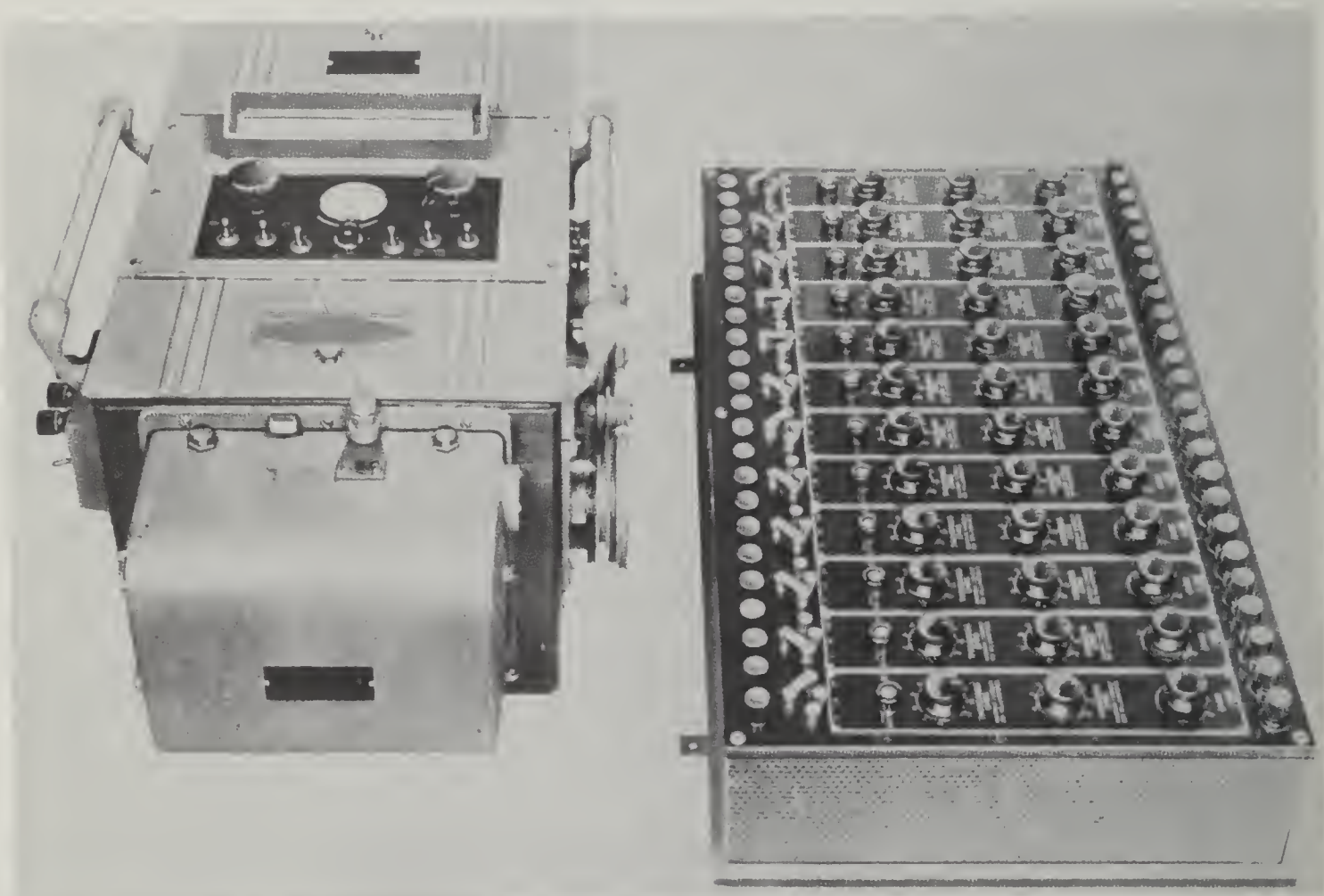


*Figure 106.1–II. Typical oscillograph with associated resistance box.*

(7) The maximum resistance should be included in the control circuit prior to application of the signal. The resistance may then be reduced to obtain the desired deflection. This affords maximum protection for the galvanometer.

(8) If an automatic delay circuit is not included in the oscillograph, sufficient time must be allowed for the drum holding the photo-sensitive paper to attain its operating speed before taking the photograph.

### 106.1.4 Harmonic Analyzer

The harmonic analyzer (fig. 106.1–III) is essentially a vacuum tube voltmeter with provisions for determining the magnitude or the relative value of voltages applied to its terminals.

To obtain the harmonics with a harmonic analyzer, the signal is connected to the input terminals and the magnitude or relative value of the component harmonics determined in accordance with instructions obtained from the manufacturer of the harmonic analyzer.

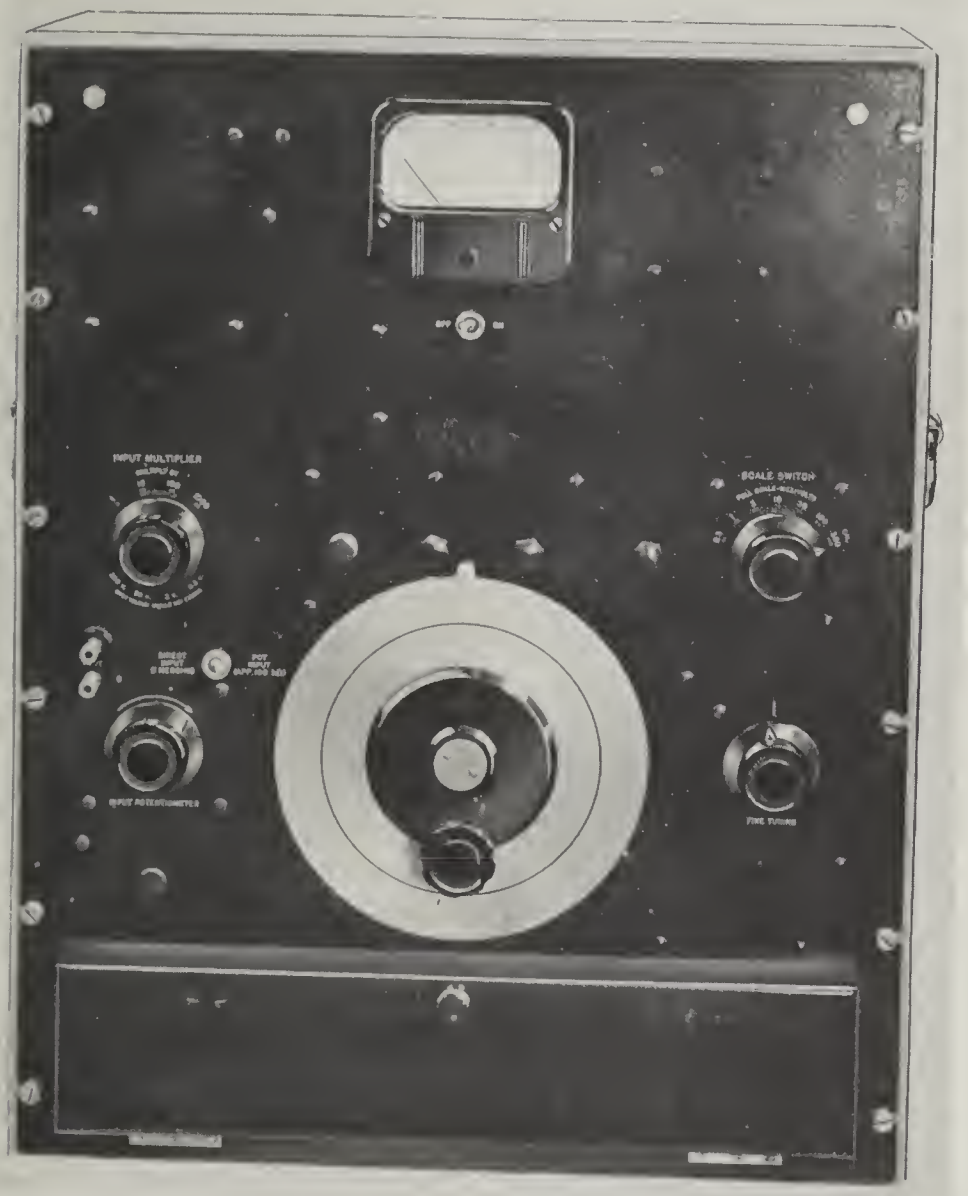



*Figure 106.1–III. Typical harmonic analyzer.*

# METHOD 107.1

# MEASUREMENT OF POWER FACTOR

## 107.1.1 General

As indicated previously in Method 103.1, the dc wattage is computed by ascertaining the product of the voltage and current in a circuit ($W=EI$). When this same mathematical process is applied to an ac circuit, the resulting answer is not necessarily a measure of the power. It is either equal to or greater than the actual power. If this product, called "apparent power" (VA, or Volt-Amps), is divided into the actual power ($W=EI\cos\theta$) of a circuit, the resulting decimal figure ($\cos\theta$) is the POWER FACTOR of the system.

When the load is entirely resistive, the power factor will be unity. If any inductance is in the circuit, the value of the power factor will be less than unity and is said to be "lagging". If capacitance is present in the circuit, the value of the power factor will be less than unity and is said to be "leading". Thus, if the power actually consumed by an inductive load is 300 watts and the product of the voltage and amperage is 500 volt-amperes, the power factor is 300/500, or 0.6 lagging.

When measuring a three-phase balanced system, that is, one in which the voltages are equal in the three phases and in which the currents are likewise equal, the formula for power is $W=\sqrt{3}\,EI\cos\theta$, where $E$ and $I$ are line voltage and current respectively. Here, again, $\cos\theta$ is the power factor.

Instruments are designed which will measure the power factor in single-phase circuits, and others are designed to measure the power factor in balanced three-phase circuits (fig. 107.1–I). No instruments are designed to measure power factor directly in unbalanced three-phase systems nor in systems in which the alternating current wave is greatly different from a sine wave. When it is desired to determine power factor in these cases, more rigorous methods of analysis are necessary. These are beyond the scope of this standard but are amply discussed in handbooks on electrical metering and instrumentation.

In measuring low values of power factor, care should be taken not to use a meter which is accurate only for high values of power factor.

In the following discussions, balanced polyphase systems and sinusoidal voltages and currents are assumed.

## 107.1.2 Instruments for Reactive Volt Amperes

Power factor may be determined from the equation:

$$PF=\cos\left(\tan^{-1}\frac{VAR}{W}\right)$$

where:

$PF$ is the power factor
$VAR$ is the reactive volt-amperes
$W$ is active power

Reactive volt-amperes may be measured on an ordinary wattmeter, providing either the voltage or current coil is excited by a signal proportional to, and vectorially in quadrature with, its normal wattmeter excitation. The two common methods of providing such excitation are described below.

*107.1.2.1 Series Reactance Method*

The potential coil excitation may be shifted 90° by the insertion of a series reactance in the potential coil circuit. This type of instrument is connected in the same manner as a standard wattmeter and may be used in any single-phase circuit, as well as in individual phases of a polyphase circuit. In order to measure VAR in a three-phase circuit, two VAR meters of this type are connected in the same manner as the wattmeters in the two-wattmeter method of measuring active power (fig. 205.1–XXI of Method 205.1). The total VAR is the sum of the readings.

*107.1.2.2 Cross-Phase Method*

In three-phase systems, the active component of current in one line is in quadrature with the

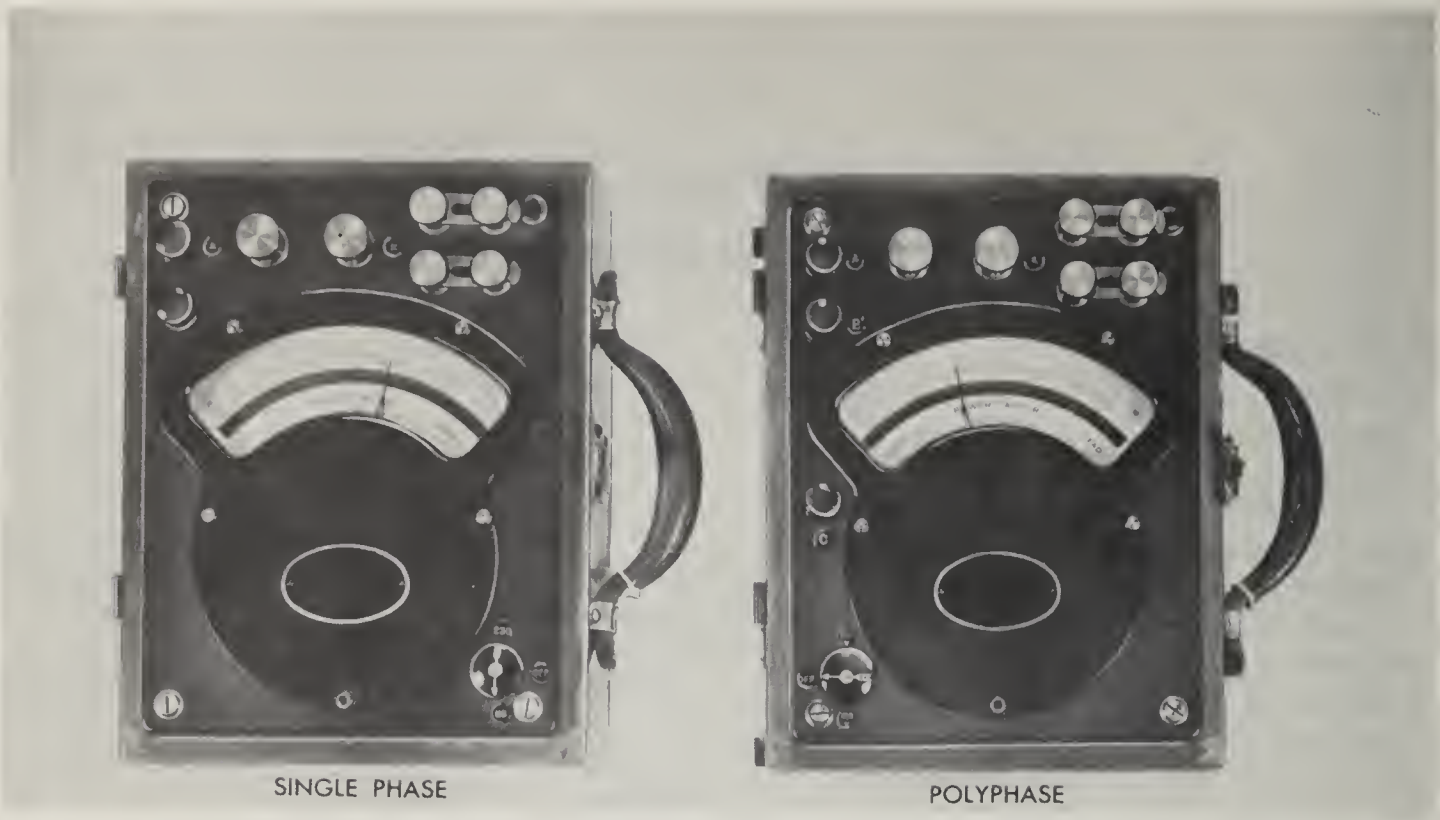



*Figure 107.1–I. Power factor meters.*

*Figure 107.1–II. Phase angle meter.*

voltage between the other two lines, while the reactive component of the same current is in phase with this voltage. Thus, an ordinary wattmeter connected with its current coil in one line and its potential coil between the other two lines indicates VAR directly. Total VAR for the system is the wattmeter reading multiplied by the square root of three.

### 107.1.3 Phase Angle Meters

Various other instruments (one type of which is shown in fig. 107.1–II), graduated in terms of either phase angle or power factor, are available for power factor measurements. These instruments may operate on any of a number of principles such as the use of phase angle itself, or the use of a mechanical comparison of the speeds of a watt-hour meter and VAR-hour meter to indicate power factor directly.

These instruments usually draw more power than the types described in paragraph 107.1.2 and generally are less satisfactory. They should be connected in accordance with manufacturer's instructions, depending upon the type to which they belong.

### 107.1.4 Two-Wattmeter Method

When active power is being measured by the two-wattmeter method, the power factor may be calculated from the two readings by applying the following formula:

$$PF = \cos\theta = \frac{W_1 + W_2}{2\sqrt{W_1^2 - W_1 W_2 + W_2^2}}$$

where:

$PF$ is the power factor

$W_1$ is the larger wattmeter reading, which is always positive

$W_2$ is the smaller wattmeter reading, which may be either positive or negative.

# METHOD 108.1

# MEASUREMENT OF TIME

## 108.1.1 General

The primary standard of time in the United States is based on astronomical observations made by the Naval Observatory at Washington, D.C. These observations are compared with quartz crystal oscillator clocks. Time signals based on these determinations are sent out by Naval Radio Stations and by Station WWV of the National Bureau of Standards. Secondary standard clocks may be pendulum controlled or synchronous clocks driven by a constant frequency source such as a tuning fork, or crystal oscillator. These secondary standards may be checked against the Observatory time by using the radio broadcasts.

## 108.1.2 Mechanical Timers

Mechanical clocks for laboratory use usually are of the stop watch kind. They are specifically designed for measuring time intervals of the order of an hour or less. The start and stop mechanisms of a stop watch and clock frequently cause errors because of lag or jumping of the sweep hand when the mechanism is operated. It is frequently more accurate to start the watch at approximately 10 seconds before zero, and then start the process to be timed as the hand sweeps through the zero. The percent of error of a stop watch may be minimized by making all time observations at least 1 minute long.

## 108.1.3 Electrical Timers

Several types of electrical timers are used to measure time intervals. The most common of these is the synchronous stop clock. This device operates in the same manner as the mechanical stop watches described above except that the hands are started and stopped by a small magnetic clutch engaging the hands with either a synchronous motor drive or a brake. Thus, the errors involved in starting and stopping are much less than those of the mechanical timers. Electrical timers of this type depend upon the frequency of the power source for their speed and are no more accurate than the power source to which they are connected. For this reason, they should never be driven by the power from an engine-generator set.

Another type of electrical timer employs a vibrating reed which is actuated by an ac signal. The reed is mounted in such manner that it will trace a line on a moving tape. This device is particularly adapted to measuring the response time of relays, contactors, and circuit breakers. The time is calculated by counting the cycles shown on the tape. The device has no appreciable starting and stopping error, but accurate knowledge of the frequency is required to translate the indications on the tape into exact time intervals. Because of the difficulty involved in counting large numbers of cycles, its chief usefulness is in measuring time intervals of from 1 to 30 cycles duration.

Electronic counters, utilizing controlled frequency supplies, are quite often used, especially where the required accuracy of the time interval measurement is high.

## 108.1.4 Oscillogram Timing Traces

Oscillograms (see fig. 425.1–III of MIL–STD–705) always require some sort of time scale if any measurements are to be made on them. The provision of such a scale is quite simple with most galvanometer types of oscillographs. A standard frequency from a crystal or tuning fork oscillator may be impressed upon the element, or a commercial power voltage may be used as a timing trace. On an oscillogram, when position is the important quantity rather than time, as in engine indicator diagrams, the timing trace may be supplied by a contactor on the engine crankshaft, or by a magnetic pickup from a slotted iron disk on the crankshaft. Cathode ray oscilloscopes (fig. 106.1–I) are less easy to time accurately. Some recent models are provided with a so-called Z-AXIS control. This acts to blank out the trace when a signal is applied. Thus, a periodic pulse may be used to dot the trace and consequently show time intervals by the distance between dots. Oscilloscopes without Z-AXIS control can be made to show a dotted trace by interrupting the signal periodically. This latter method is much more difficult to calibrate and should be avoided wherever possible.

# METHOD 109.1

# MEASUREMENT OF SPEED

## 109.1.1 General

Speed of rotation is derived by counting revolutions and measuring elapsed time. This operation may be performed very accurately by means of a counter and electric clutch, automatically timed by a synchronous clock and a standard frequency source. One commercially available device of this type is called a chronotachometer and is shown in figure 109.1–I.

Rotational speed may be translated to frequency by the use of an ac generator driven by the rotating element. This then may be measured electrically (see Method 104.1).

## 109.1.2 Speed Counters

One of the ways to measure speed during a test is to count revolutions for a measured time interval. This may be done by observing the readings of a counter permanently attached to the machine shaft, or by temporarily attaching a counter to the shaft, through a friction wheel or disk. In either case, the duration of the observation should be great enough to minimize all the errors due to starting and stopping the stop watch or counter. In the case of a portable counter, which, in use, is started and stopped, either the counter should be started as the clock hand sweeps through zero, or vice versa. No attempt should be made to start both the counter and stop watch simultaneously.

## 109.1.3 Direct Reading Tachometers

Several methods are used to indicate speed directly. Among them are the position of centrifugal fly-balls, the voltage of a magneto, the pressure of a centrifugal hydraulic pump, and the eddy-current drag of a rotating magnet on a conducting disk. Each of these devices may be used as a tachometer, and each has its own advantages and disadvantages. Direct reading tachometers are available either for positive connection to the machine under test, or for hand use. The latter are shown in figure 109.1–II.

For the purpose of testing generator sets, the hand-type tachometers should never be relied upon for actual test data. They may be used for rough adjustments, but all data should be obtained from positively driven tachometers (fig. 109.1–I), or speed counters.

Recording tachometers (fig. 109.1–III) are available. These usually are powered by direct-connected or belt-driven tachometer generators.

## 109.1.4 Stroboscopes

Stroboscopes, shown in figure 109.1–IV, are devices for producing periodic light flashes of high intensity and short duration. If a piece of moving machinery is illuminated by such a light source, an observer sees the machine only during the periodic light flashes. If the period is adjusted to coincide with a periodic movement or rotation of the machine, the machine will appear to stand still. Any deviation from syncronism will appear as a slow movement of the machine through its operating cycle. Therefore, if the frequency of the light is held constant, the machine speed may be held constant by keeping it "standing still". Also, if a disk having radial stripes is mounted on the machine as a target for the stroboscope, and the stroboscope is excited with a constant frequency, the machine speed may be held to any integral multiple or fraction of the stroboscope frequency. *For example:* if the stroboscope is excited with 60-cycle power, it will flash at a rate of 120 flashes per second, or 7,200 flashes per minute. If seven stripes are painted on the target disk at equal intervals, it will appear to stand still when the light flashes seven times during each revolution, or, in other speeds, synchronization may be obtained by the use of other numbers of stripes. This characteristic, though useful for holding various speeds, makes it very difficult to use a stroboscope as the only speed measuring device. Instead, the stroboscope should be used only as an aid to hold a machine

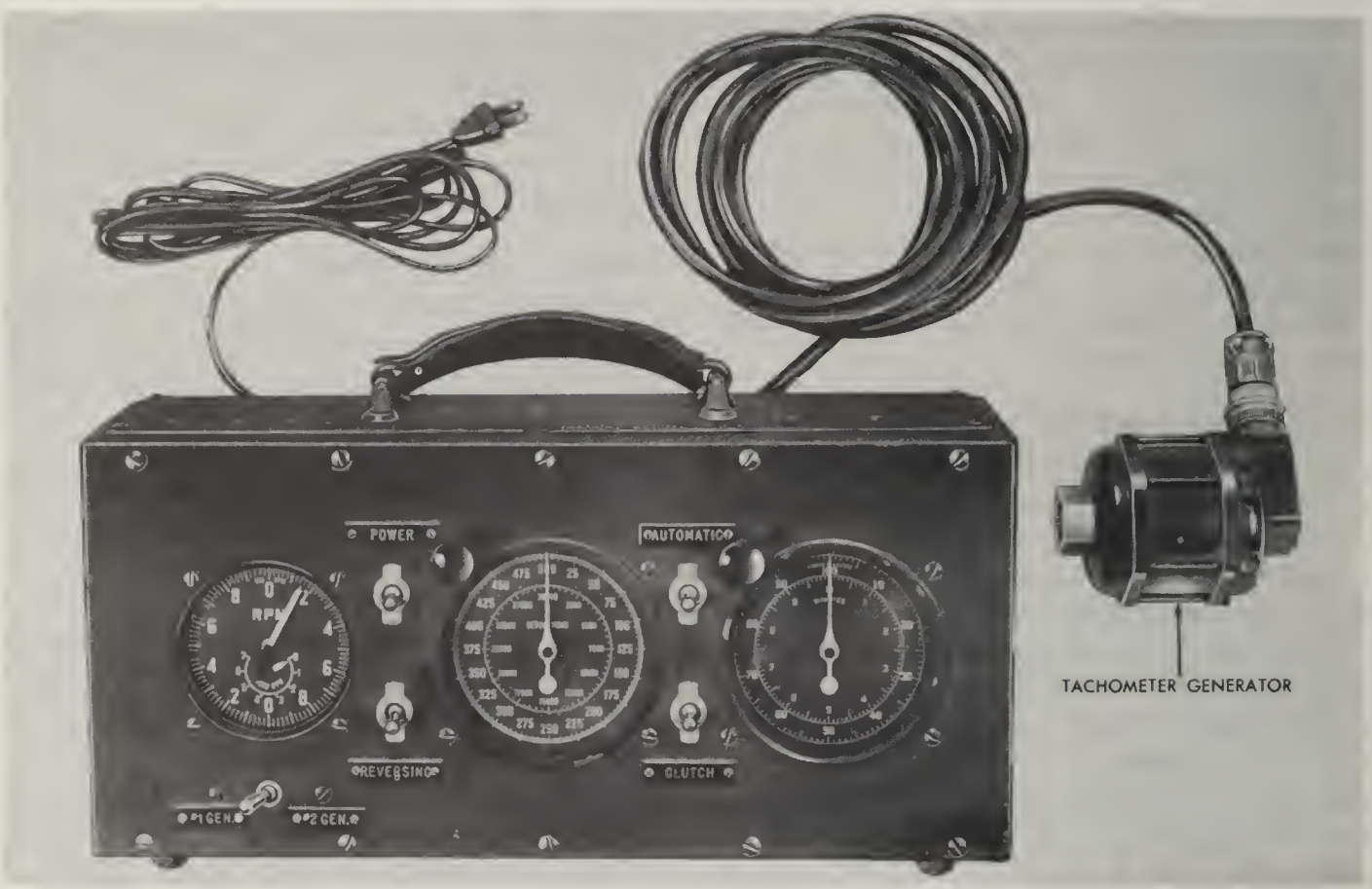



*Figure 109.1–I. Representative type of speed and revolution counter.*

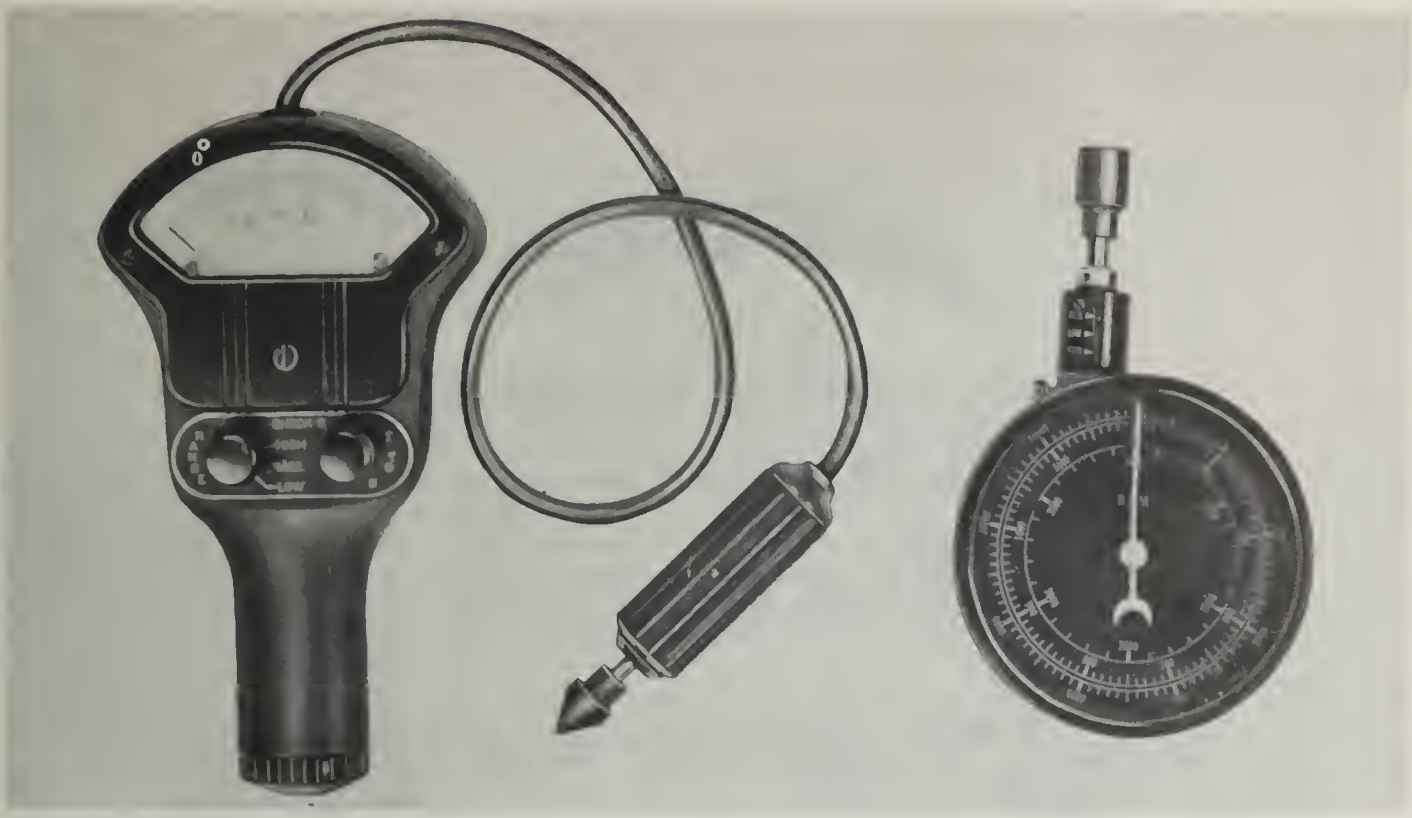


*Figure 109.1–II. Representative hand-type tachometers.*

speed constant after the speed has been determined by some other means.

A device known as a strobotac (shown at the left of fig. 109.1–IV), which excites a stroboscopic light by means of the output of a variable oscillator, is commercially available. Because of the great difficulty in accurately calibrating an oscillator of this type, these instruments should never be used as a source of final test data, but may be used to obtain rough data and as an aid to maintain the machine speed constant after the speed has been determined by other means.

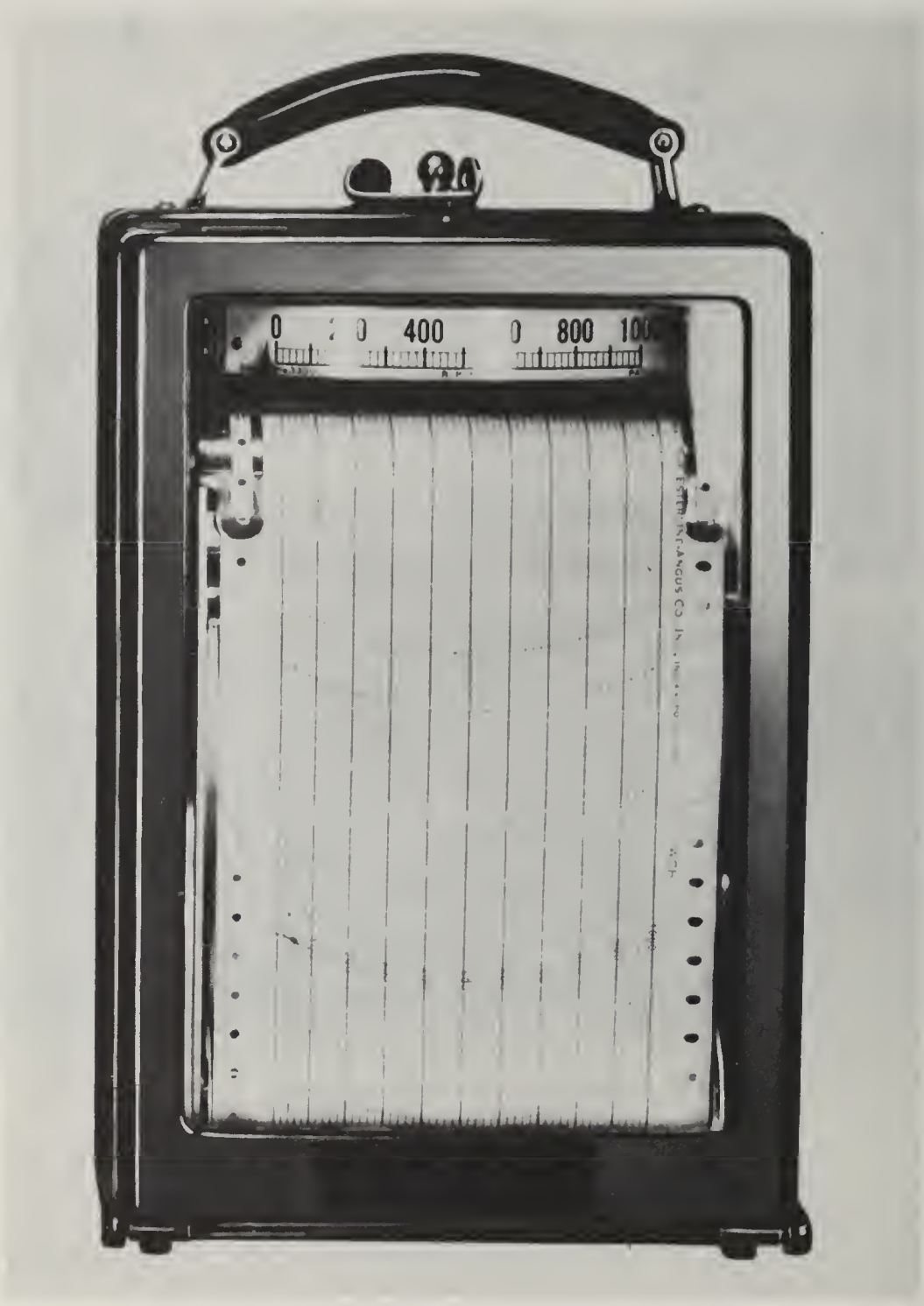



*Figure 109.1–III. Acceptable type of recording tachometer.*

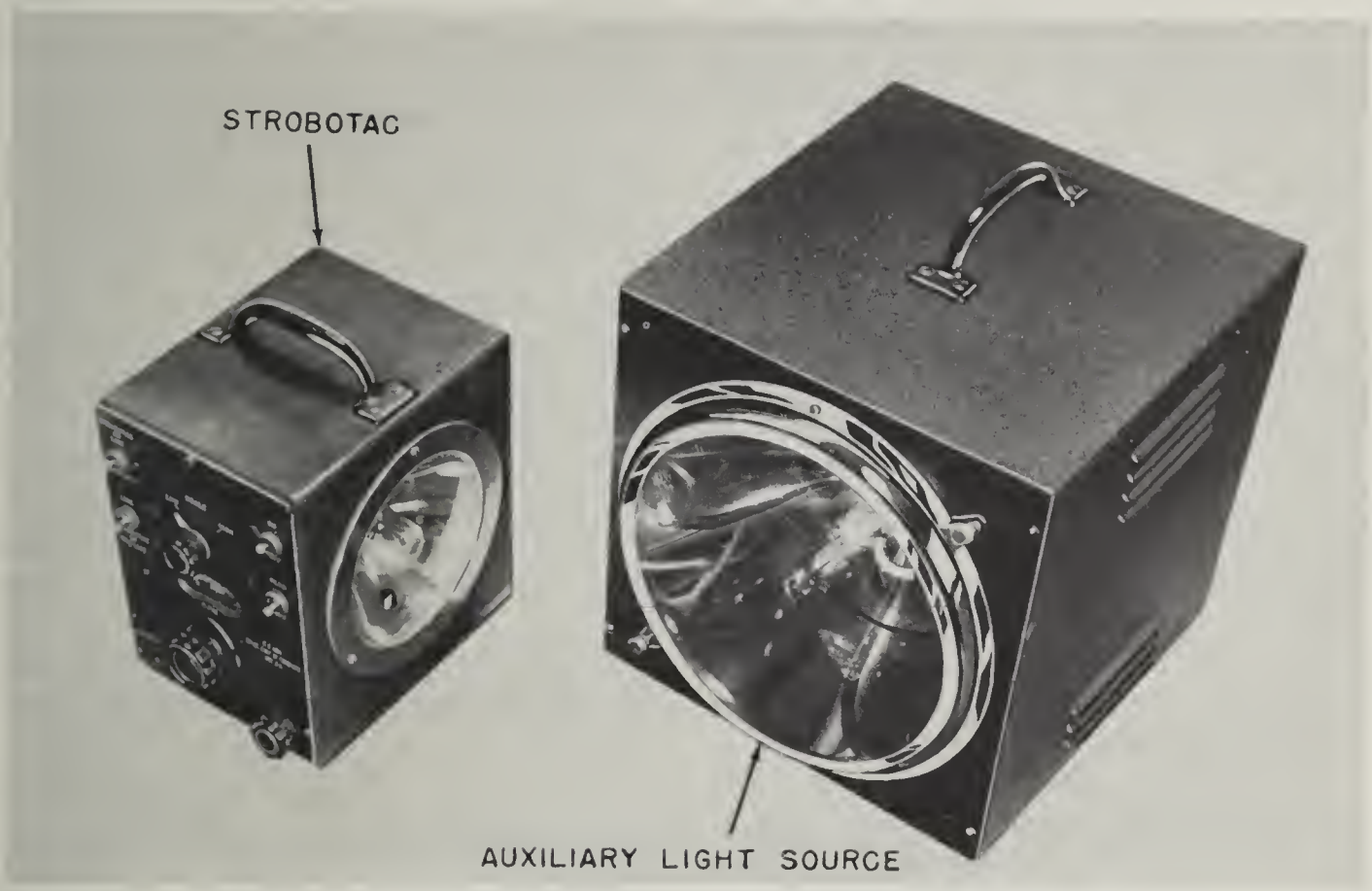



*Figure 109.1–IV. Stroboscopic tachometer with auxiliary light source.*

# METHOD 110.1

# MEASUREMENT OF TEMPERATURE

## 110.1.1 General

There are three methods used to determine temperatures of various components of an engine-generator set, as well as the temperatures of coolants, lubricants, etc. These three methods are: contact, resistance, and embedded detector.

The temperature rise of certain components and materials during operation of the generator set is an important characteristic. Temperature rise is defined as the difference between the temperature of the component or material, and the ambient temperature, at a point in operation of the generator set where temperatures have stabilized. Temperature stabilization of a component is reached when consecutive readings, taken at 15-minute intervals, of an individual component or material, are the same, or within the limits of variation as specified in the procurement documents.

The limits of temperature rise for various components and materials are given in the procurement documents.

## 110.1.2 Contact Method

The contact method consists of determining temperature by placing a mercury or alcohol thermometer, a resistance thermometer, or a thermocouple in direct contact with the component or material whose temperature is to be measured.

When these devices are used in connection with the measurement of surface temperatures, they shall be covered with oil putty, or a felt pad. The covering material is used to protect the temperature device from the air above the surface but should not be so large as to interfere with the natural cooling of the surface by circulation of the ambient air.

Thermometers with broken columns of mercury or alcohol should not be used.

During use, the thermometer bulb shall not be located higher than any other part of the thermometer.

A thermocouple consists of two metals in contact with each other. The two metals are of different molecular structure, and electromotive force is produced when a temperature change is introduced at the junction of the two metals. The emf varies with each temperature change. Thermocouples are fabricated in different shapes and in different combinations of metals to suit individual locations and for different ranges in temperature (fig. 110.1–I). These thermocouples are used in connection with various types of thermal potentiometers which indicate temperature in degrees, or in numbers which can be converted to degrees. One such device is shown in figure 110.1–II. This type is self-contained, having the selector built into the unit. Another type employs a separate selector for use with several thermocouples.

A resistance thermometer type of recording instrument is shown in figure 110.1–III.

A recording thermal potentiometer, for use with thermocouples, is shown in figure 110.1–IV.

To determine the temperature rise, convert both the ambient temperature readings and the maximum contact device readings to degrees Centigrade (par. 110.1.5). Then subtract the ambient from the contact readings.

## 110.1.3 Resistance Method

The resistance method determines temperature by the comparison of the resistance of a winding, at the temperature to be determined, with the resistance of the winding at a known temperature. Since a small error in measuring either the hot or cold resistance will make a comparatively large error in determining the temperature rise, the Wheatstone or Kelvin bridge method of obtaining resistance (see Method 105.1) should be employed to assure accuracy. This method utilizes that

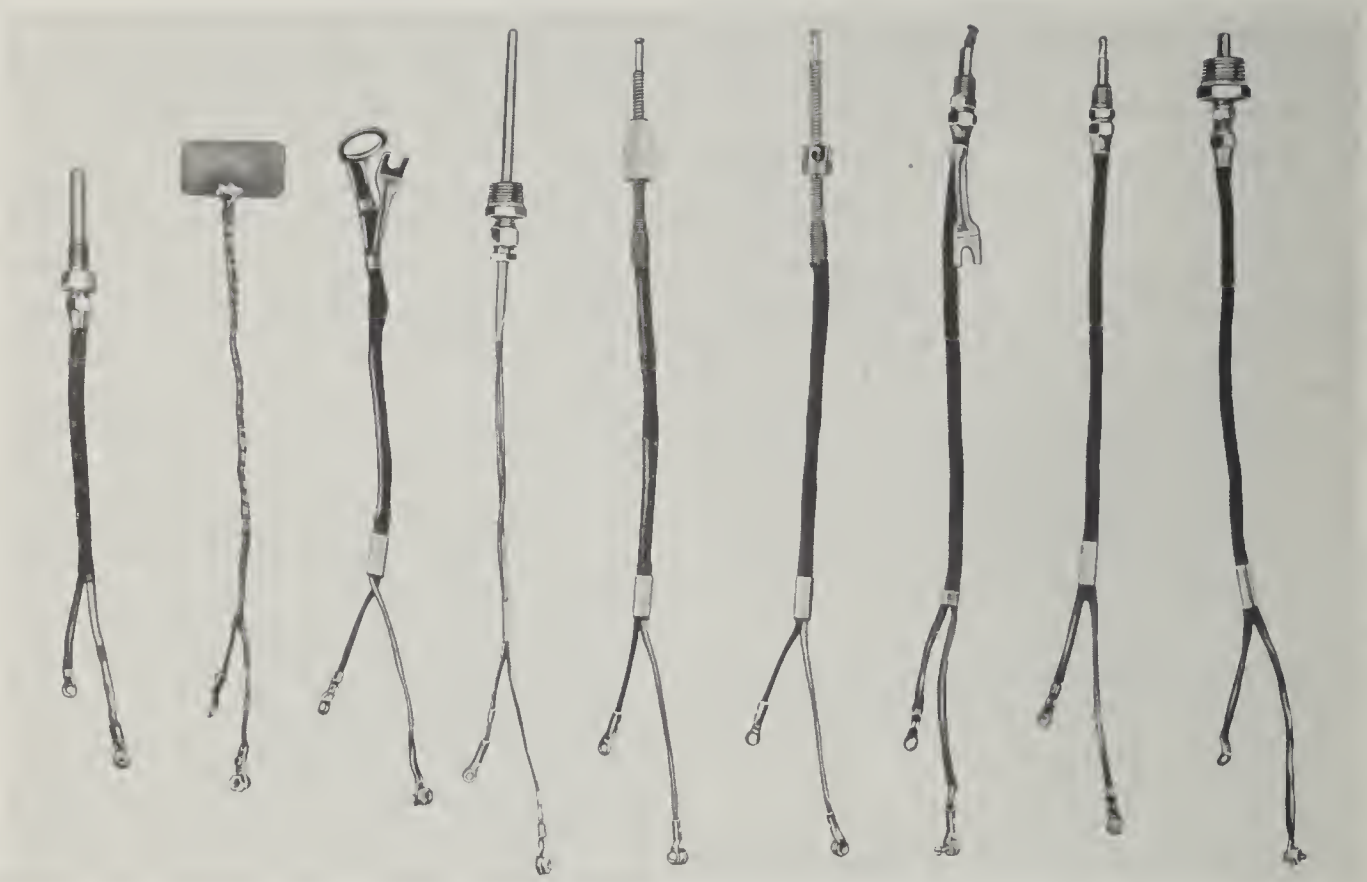


*Figure 110.1-I. Various types of thermocouples.*

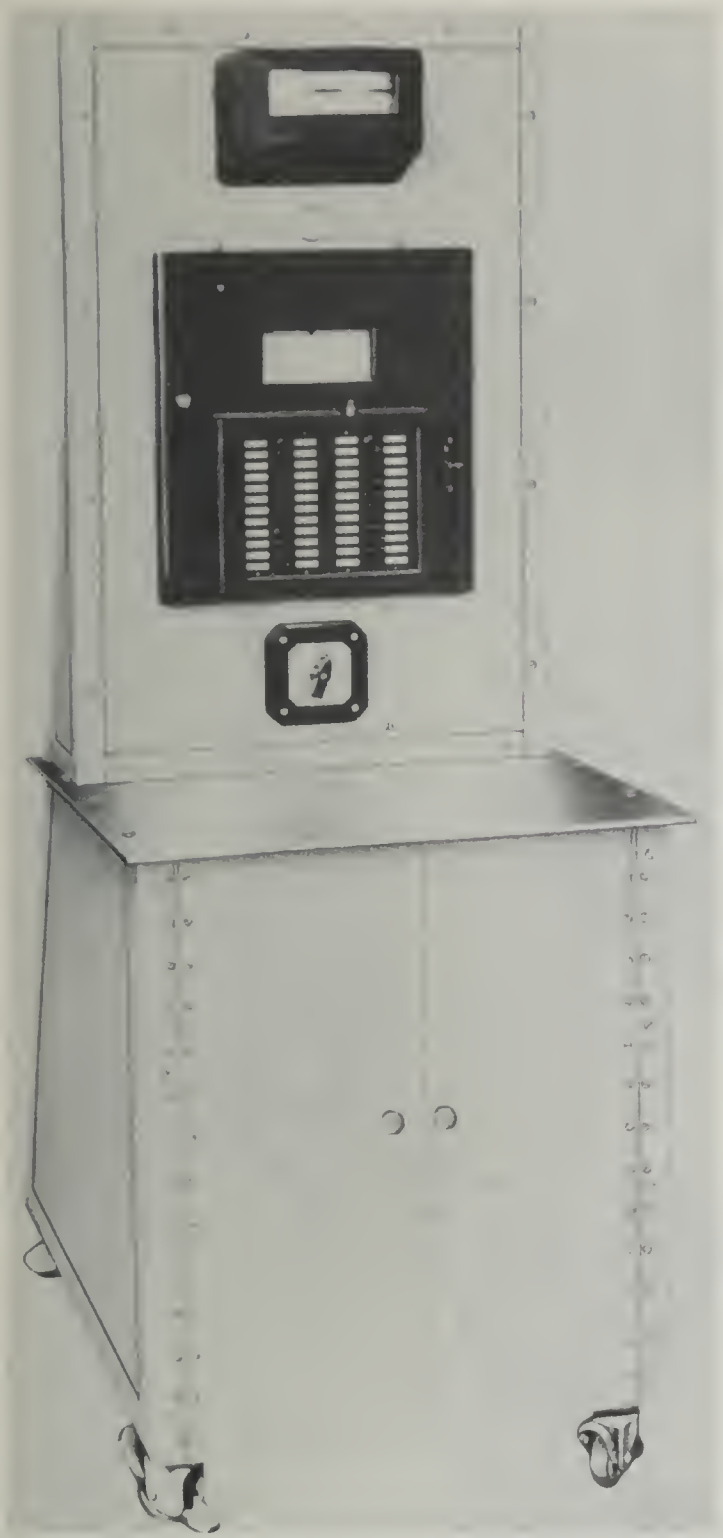


*Figure 110.1–II. Indicating thermocouple potentiometer.*

characteristic of copper whereby a change of resistance is proportional to a change of temperature. The following steps will be followed in determining the temperature rise by this method.

(1) The resistance of the winding at known temperature shall be obtained.

(2) The device being tested shall be operated as prescribed by the test method until it reaches the condition at which the temperatures or temperature rise of the winding is to be obtained.

(3) The ambient air temperature at this time shall be recorded and if in degrees F., it shall be converted to degrees C.

(4) The hot resistance of a dc field winding may be computed from the ammeter and voltmeter readings, as follows:

$$R_h = \frac{V_{cf}}{I_{cf}}$$

where:

$R_h$ is the hot resistance of the field winding

$V_{cf}$ is the voltage across the field winding

$I_{cf}$ is the current in the field winding

(5) The above method may be used on the stationary fields but should not be used on rotating fields. However, the method described in (6) below, is preferred.

(6) The Kelvin or Wheatstone bridge will be used to determine the hot resistance of the generator armature, exciter armature, and the generator field except in the case of rotating windings of less than 1 ohm resistance (see Method 105.1).

(7) The drop-in-potential method will be used to obtain the hot resistance of rotating windings of less than 1 ohm resistance (see Method 105.1).

(8) To determine the hot resistance by either the bridge method or drop-in-potential method, the following shall be observed:

(*a*) The generator will be shut down.

(*b*) A reading shall be made immediately (in less than 45 seconds, if possible).

(*c*) Repeated readings will be made at intervals of 15 to 30 seconds for at least 3 minutes. If the resistance is increasing at the end of 3 minutes, readings shall continue until the resistance begins to decrease.

(*d*) A stop watch will be employed to determine time from shutdown to the initial reading and between subsequent readings (see Method 108.1).

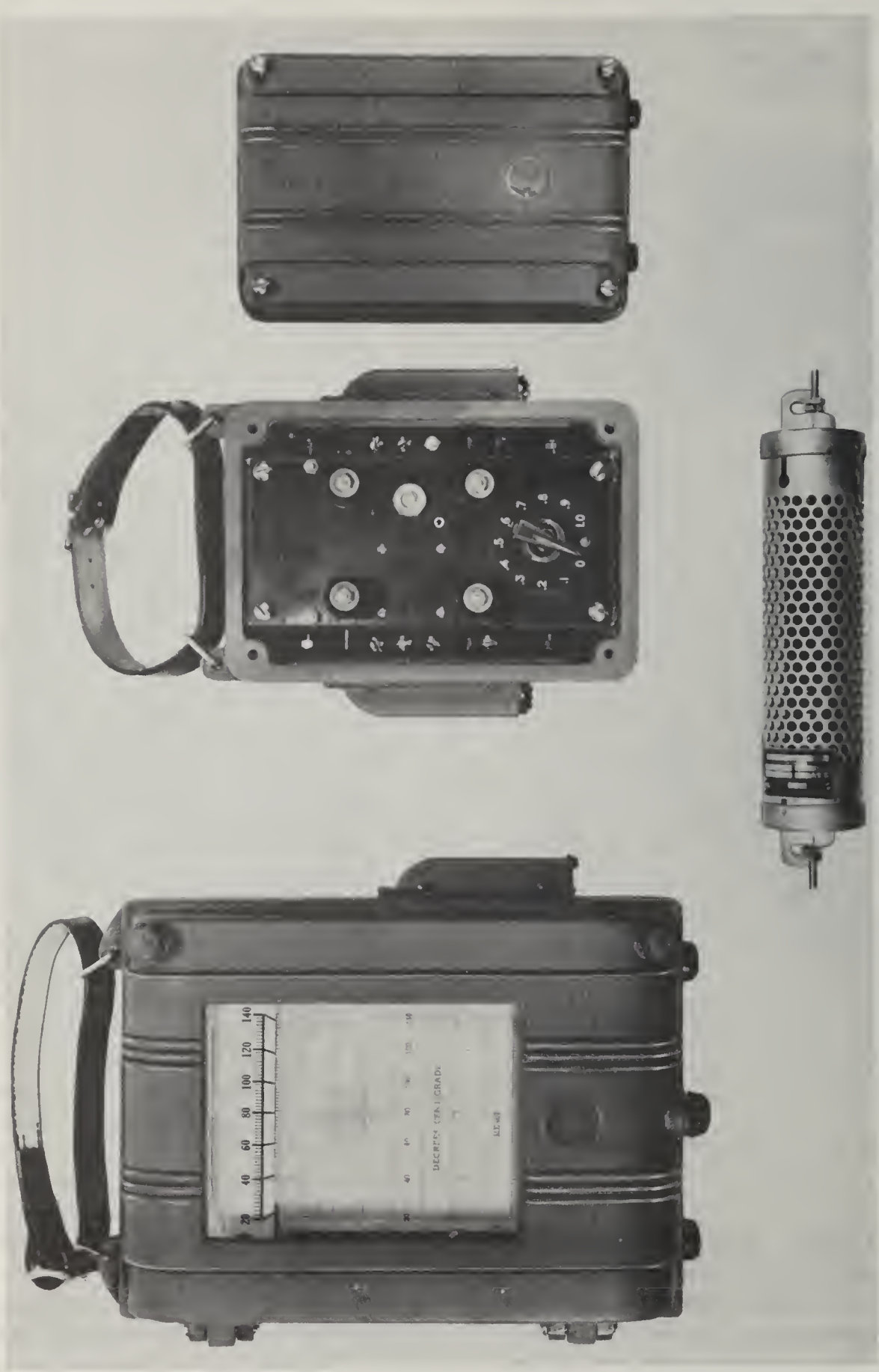


*Figure 110.1–III. Resistance thermometer type of recording instrument.*

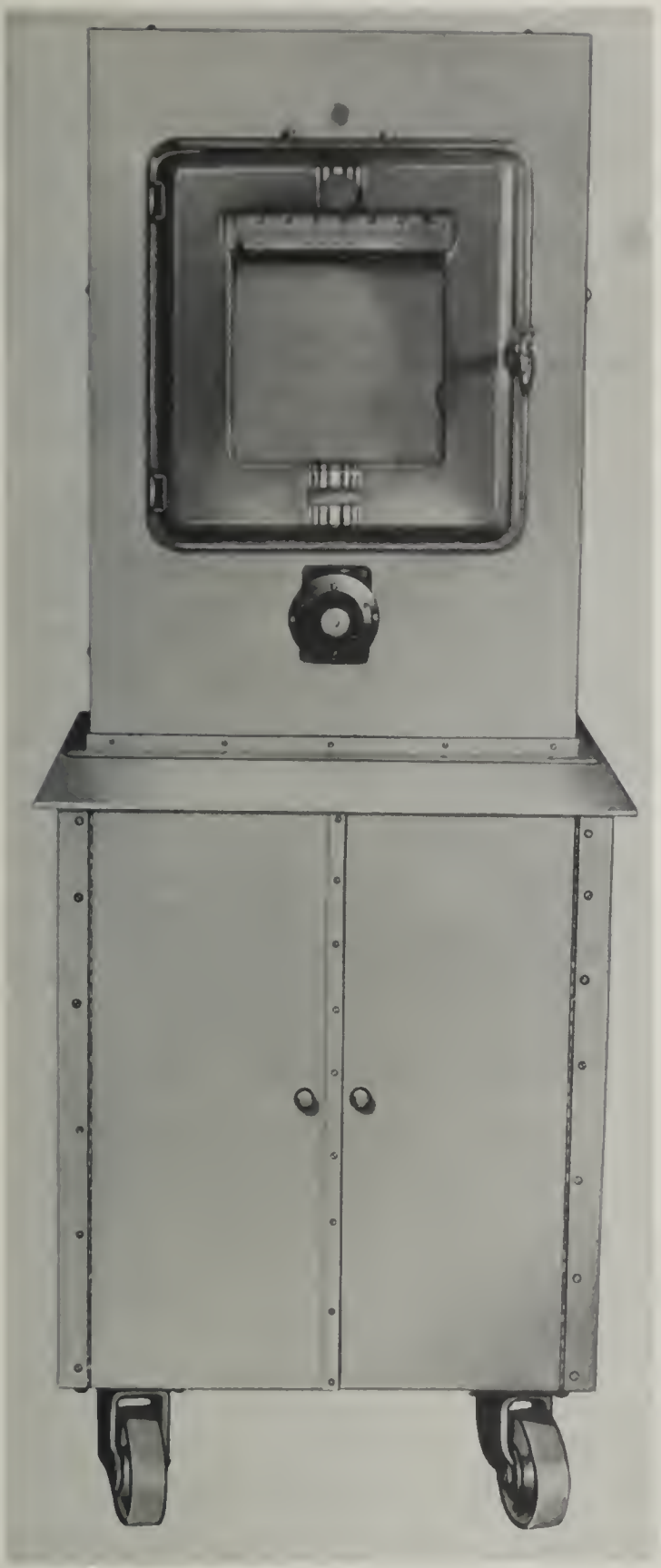


*Figure 1110.–IV. Recording thermal potentiometer.*

(*e*) The resistance readings will be plotted against time on semilogarithmic paper. Time will be plotted along the divisions of equal size and resistance will be plotted along the logarithmic divisions. This curve will be extrapolated (extended) from the first reading back to the time of shutdown. The highest resistance on the curve will be used as the hot resistance.

The temperature rise for copper windings is calculated from the formula:

$$T_r = T_h - T_a = \frac{R_h}{R_c}(234.5 + T_c) - (234.5 + T_a)$$

where:

$T_r$ is the temperature rise

$T_h$ is the temperature of the winding in degrees C. when hot resistance ($R_h$) was measured

$T_a$ is the ambient temperature

$R_h$ is the hot resistance

$R_c$ is the cold resistance

$T_c$ is the temperature of the winding in degrees C. when cold resistance ($R_c$) was measured

### 110.1.4 Embedded Detector Method

The embedded detector method of determining temperature employs thermocouples or resistance temperature detectors built into the machine. Usually they are used on machines rated above 500-kw and then only if other means of temperature measurement are not practicable.

The embedded resistance temperature detector is a resistance of a known value at a specific temperature.

To determine a temperature with an embedded resistance detector, accurate measurement of the detector resistance will be made (see Method 105.1) and the temperature calculated from the formula:

$$T_r = T_h - T_a = \frac{R_h}{R_c}(234.5 + T_c) - (234.5 + T_a)$$

(The above formula applies only to copper windings.)

where:

$T_r$ is the temperature rise

$T_h$ is the temperature of the detector in degrees C. when $R_h$ is measured

$T_a$ is the ambient temperature

$R_h$ is the hot resistance

$R_c$ is the known resistance of the detector at $T_c$ degrees C.

$T_c$ is the temperature of the detector in degrees C. when the known resistance ($R_c$) was was measured.

### 110.1.5 Converting Fahrenheit to Centigrade, and Vice Versa

To convert Fahrenheit to centigrade:

$$C.= \frac{5}{9} (F.-32)$$

To convert centigrade to Fahrenheit:

$$F.= \frac{9}{5} C.+32$$

When converting a temperature rise from degrees Fahrenheit to degrees centigrade, and vice versa:

Temperature rise in degrees C.=5/9 (Temperature rise in degrees F.)

Temperature rise in degrees F.=9/5 (Temperature rise in degrees C.)

*Note.* You will note that the addition or subtraction of 32° is not concerned in the above formulas relating to temperature rise because you are converting a difference in temperatures rather than a temperature.

# METHOD 111.1

# MEASUREMENT OF WEIGHT AND FORCE

## 111.1.1 General

Weights, operating forces, spring tensions, and brake torques are measured on one of the following instruments:

## 111.1.2 Platform Balances

Platform balances are the most accurate means of measuring force that are readily available, and they should be used in preference to other means whenever practicable. They should be used for all fuel consumption and other weight measurements.

A platform balance should be inspected before use to insure that the beam swings freely and to determine if the balance has any zero error. Balances should be proved every six months to insure that their calibrations remain constant.

Platform balances should not be used where they will be subject to shock or serious vibration, because of the danger of damaging the knife-edge pivots of the instrument.

Platform balances must be level when in use.

## 111.1.3 Spring Balances

Spring balances are much more convenient to use for most force measurements than are platform balances. However, spring balances usually are less accurate. Spring balances may be used in any position, but the zero error should be noted with the balance in the position in which it is to be used.

Spring balances are most useful for measureing such quantities as brush pressure, valve spring pressures, and operating forces of all kinds. In these measurements it is necessary to use care in order to avoid errors due to friction in the balance. Spring balances are subject to calibration errors due to changes in the spring tension which may occur in normal use. Therefore, these balances should be checked frequently.

# METHOD 112.1

# MEASUREMENT OF PRESSURE

## 112.1.1 General

The following instruments are used to measure any of the various fluid pressures encountered in testing engine-generator sets.

## 112.1.2 Deadweight Gages

The most accurate pressure-measuring instruments for gage pressures above one atmosphere are deadweight gages. These devices employ a small piston loaded with a known deadweight to balance the pressure of oil in a vertical cylinder below the piston. Accurate measurements of the piston area and value of the deadweights are easily obtained so that the instrument can be very accurately calibrated. The only remaining source of error is static friction and this is eliminated by rotating the piston and weights about their vertical axes. These instruments can be used, however, only for constant pressures greater than atmospheric, as they are not direct reading instruments. They are most useful as standards for relatively high pressures, to be used to calibrate other instruments.

## 112.1.3 Manometers

Liquid manometers (fig. 112.1–I) always consist of two chambers partially filled with a liquid and connected so that the liquid is free to flow from one to the other. A pressure applied to the liquid in one chamber is communicated to the other chamber only through the liquid. If the pressures in the two chambers are unequal, the liquid will flow from one chamber to the other until the unbalanced pressure is exactly offset by the unbalanced liquid head. If the density of the liquid is known, the pressure can be computed from the measured difference between the liquid levels. The liquid used in manometers may be water, mercury, alcohol, oil, or any other, depending upon the pressures to be measured. Manometers always measure a pressure difference. Therefore, the absolute pressure on one chamber must be known before the absolute pressure on the other chamber can be calculated. For measuring pressure differences such as the drop across an orifice, or in a venturi, the manometer is connected to show the difference directly. Manometers are simple, direct reading, accurate instruments that can be used for a wide range of applications and for pressures both above and below atmospheric. They are impractical for use with pressure differences much greater than one atmosphere, but anywhere within their useful range, their accuracy and simplicity make them the preferred type of instrument for static or slowly changing pressures.

## 112.1.4 Mechanical Gages

Pressure gages making use of bellows and bourdon tubes to change pressure into a mechanical reading are available for all ranges of pressures encountered in testing engine-generator sets. These instruments are convenient to use, direct reading, and durable. They must not be subjected to pressures greater than their ratings, nor to high temperature gases because either condition may destroy the calibration. Because of their low mass moving systems, they are better adapted to the measurement of changing pressures than either of the types previously discussed. Mechanical gages are available with ranges above and below atmospheric pressure, although they usually indicate only gage pressure. Both indicating and recording types are available.

## 112.1.5 High-Speed Mechanical Gages

For the measurement of dynamic pressures such as firing pressures in an engine, and diesel fuel-injection pressures during operation, instruments having very high-speed response are necessary. This is achieved mechanically by limiting the number of moving parts to a small piston and spring, or a small diaphragm, and restricting the motion of these parts to a few thousandths of an inch. This motion usually is detected electrically

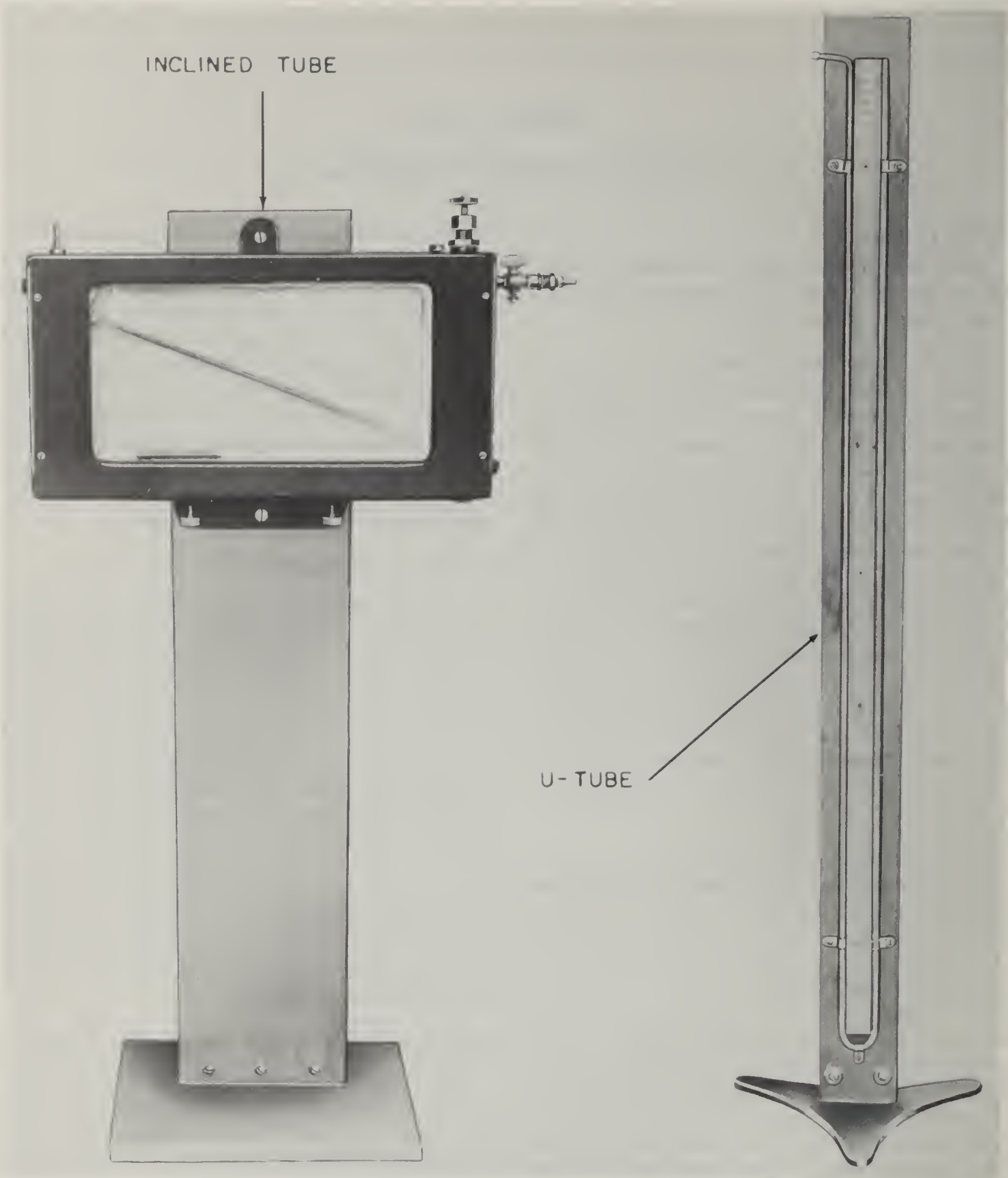



*Figure 112.1–I. Representative types of manometers.*

by the opening or closing of a pair of contacts. Two methods are employed to secure a reading from such an instrument. One method uses a calibrated spring to oppose the motion of the piston or diaphragm. The other uses compressed gas and a standard pressnre gage. In either case, the opposing force is increased until the contacts just fail to close, as indicated by a neon light energized through them. The peak test pressure is then equal to the value of the opposing force. A variation of this instrument is the Parnsboro Engine Indicator. In this instrnment, a sensitized drum is rotated in synchronism with the engine crankshaft. A stylus near the drnm moves along it in proportion to the value of the force opposing the gage piston. Each time the contacts open or close, an external spark coil causes a spark to pass from the stylus to the drum, thus marking the drum. To operate the instrument, the piston force is gradually increased from zero while the engine being tested is running under the desired condition. As soon as the sparking ceases, the drum is stopped. It then will show a complete record of cylinder pressure against crankshaft position, as a series of dots on the drum. All of these mechanical instruments are subject to errors due to differences in the dynamic and static calibrations, and dne to mechanical resonance effects in the instrument itself. However, they are convenient to use and easy to calibrate statically.

### 112.1.6 High-Speed Electrical Gages

Some of the disadvantages of the mechanical instruments described above are overcome by using electrical pickups. In these devices, a stiff diaphragm usually is mounted flush with the surface of the engine combustion chamber. Its motion is then measured electrically and recorded by an oscillograph. Because of the lack of long, narrow passages, resonance is avoided in the combustion gases, and, because of the low-mass-elastance ratio, mechanical resonance is avoided in the diaphragm. The instrument can be made sensitive to very high-frequency impulses, depending upon the response of the connected electrical circuit. These instruments are much more difficult to calibrate than the mechanical instruments, and are subject to additional errors introduced by the external electrical circuits. In general, they are not readily available, and must be especially designed for each application. Despite these faults, they are the best available means of actually determining what is occurring inside the combustion chambers of modern high-speed engines.

# METHOD 113.1

# EXHAUST GAS ANALYSIS

## 113.1.1 General

One method of checking the air-fuel ratio supplied to an internal combustion engine is to analyze the exhaust gas of that engine. Either of the following instruments may be used to secure an analysis of engine exhaust gases.

## 113.1.2 Orsat Apparatus

The Orsat apparatus is a device for obtaining the chemical analysis of exhaust and flue gases. The process consists of drawing into the apparatus a measured volume of the exhaust gas, then passing this quantity of gas successively through different absorption solutions and measuring the reduction in volume effected by each solution. After these have been accurately measured, the air-fuel ratio can be determined by the use of a conversion chart which is part of the apparatus.

## 113.1.3 Wheatstone Bridge Gas Analyzer

The wheatstone bridge gas analyzer (fig. 113.1–I) contains a platinum wire for one resistance. This wire is heated to a low red heat by a current passing through the bridge. The wire is located in a chamber through which the exhaust gas, together with a definite ratio of air, is made to flow continuously. Any combustibles in the exhaust gas are ignited and burned along the surface of the platinum wire, raising the temperature still further. The temperature change in the wire causes a change in resistance which deflects the galvanometer within the bridge. The bridge galvanometer may be graduated in terms of "percent carbon dioxide" which can be converted into air-fuel ratio through the use of a conversion chart.

*Figure 113.1–I. Wheatstone bridge gas analyzer.*

# METHOD 114.1

# TEMPERATURE CONTROL

## 114.1.1 General

Test chambers in which temperatures are very accurately controlled are called "hot rooms" or "cold rooms". Hot rooms can be easily constructed in most plants and their construction details are described and illustrated in this section. Cold rooms are very difficult to construct and most plants make no attempt to build them, but use testing facilities of an established testing organization. Due to their complexity, cost, and possible variance, no attempt will be made to give details or illustrations of cold rooms in this handbook.

The following paragraphs are a discussion of hot rooms.

## 114.1.2 Control of Temperature

Hot rooms used to test engine-generator sets must have adequate temperature control to meet the requirements of the high temperature test. The air temperature must be uniform within 5° C. around the set, and it must not vary more than 5° C. throughout the test. A typical hot room, capable of maintaining such temperature control is shown in figure 114.1–I. The hot room should have provisions to heat the intake air, to recirculate a certain amount of the heated air, to admit fresh air, to keep all the air in the room circulating, and to allow the excess heat and engine exhaust to escape. The recirculated air should not return within the hot room, but should be conducted around the chamber in a separate duct.

## 114.1.3 Size of Hot Room

The hot room should be large enough so that the walls are at least 6 feet away from the engine-generator set under test. It may be necessary to use air baffles and deflectors in the room to maintain good temperature control, and, as long as these are at nearly the same temperature as the ambient air in the hot room, they may be placed closer to the generator set than 6 feet. The room should be at least 3 feet higher than the engine-generator set being tested. If the room has an inner screen or false wall with the air passing on both sides of it so that it is uniformly at the hot-room ambient temperature, this screen or wall may be less than 6 feet, but not less than 3 feet, from the engine-generator set. In this case, the outer wall of the hot room may be as close to the screen as desired, provided that the ambient air is made to circulate between the screen and the outer wall.

## 114.1.4 Air Circulation in Hot Room

The air in the hot room shall be in continuous motion to prevent the formation of local conditions within the room which are different from the average in the room. However, the air velocity should not exceed 5 miles per hour anywhere in the room except at the cooling air exhaust openings. In general, it is easier to control the conditions in the hot room if the air flow is from the generator-end of the engine-generator set toward the engine-cooling-air exhaust. The air flow in the room should neither aid nor hinder the normal cooling of the set during operation.

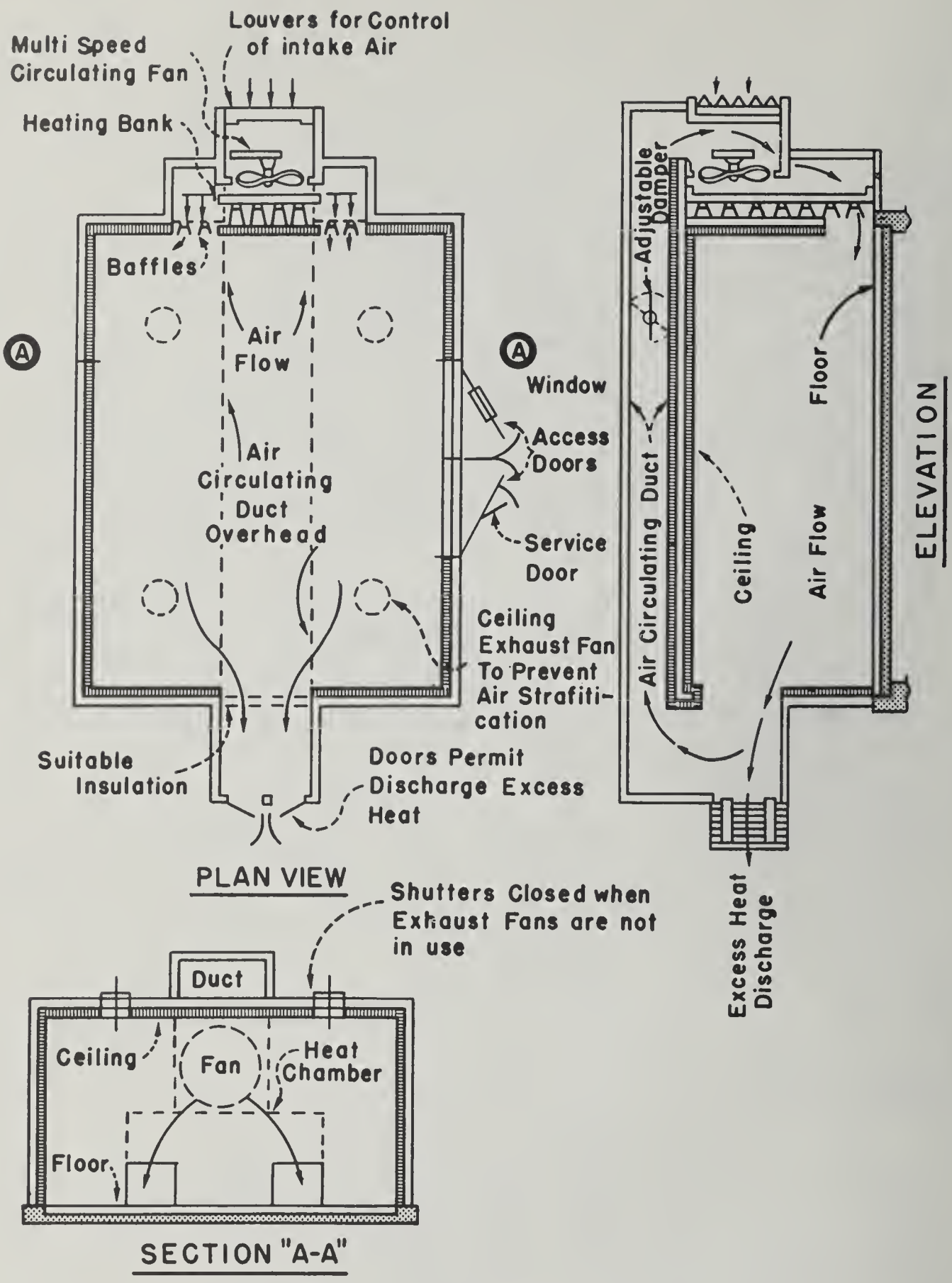



*Figure 114.1–I. Layout for typical hot room.*

# METHOD 115.1

# MEASUREMENT OF SOUND LEVEL

## 115.1.1 General

For some applications it is desirable that an engine-generator set operate as quietly as can be made possible without impairing its operating efficiency. Some manufacturing specifications contain requirements for limits of operating noise, in terms of units of the standard reference sound level. The standard reference level is defined as 0.0002 microbar (a pressure of 0.0002 dyne per square centimeter) at 1,000 cycles per second.

The testing procedure to determine the degree of sound level of a generator set is given in Test Method 661.2 of MIL–STD–705.

## 115.1.2 Sound Level Meter

A sound level meter (fig. 115.1–I) is an instrument for reading, in terms of a standard reference sound level, the sound level at its microphone. The instrument consists essentially of a microphone, electronic amplifying and filtering equipment, and an indicating meter.

This instrument is extremely sensitive to sound from any source. Therefore, to accurately determine the noise characteristics of a generator set, the test should be made preferably in a quiet rural area where sources of sound other than from the unit under test are at a minimum.

When testing, the sound level meter is placed at a fixed distance from the generator set. This distance is specified in the procurement documents. Readings of the instrument normally are taken at four locations, one at each side, and one at each end of the generator set.

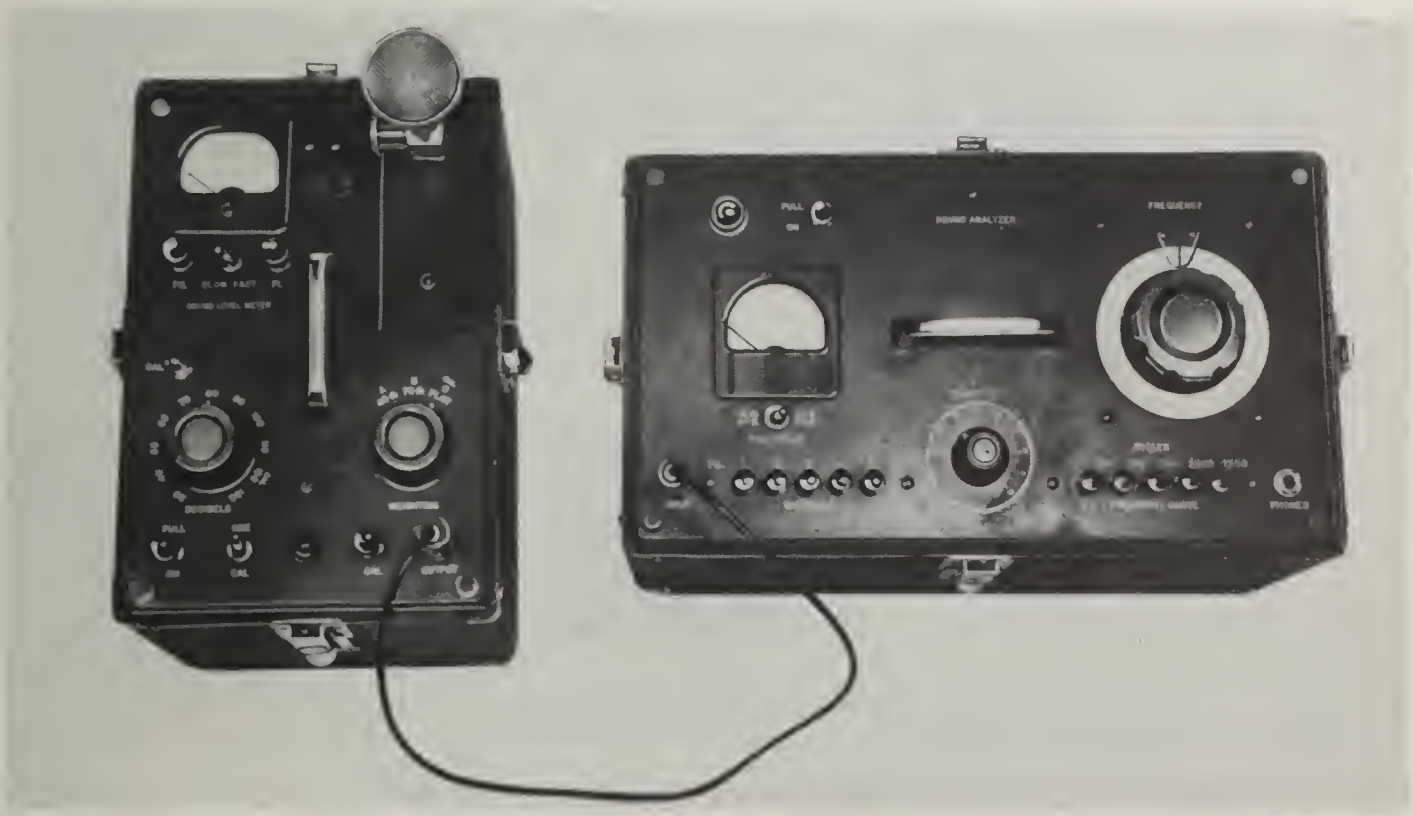


*Figure 115.1–I. Sound level meter.*

# METHOD 116.1

# DETERMINATION OF PHASE ROTATION

## 116.1.1 General

During any cycle, an ac voltage varies from zero volts to a maximum, then to a minimum, and finally back to zero.

When each of the voltages of a three-phase ac system are observed simultaneously, it is noted that the time of arrival at the maximum voltage of each of the phases is different. If phase one reaches a maximum first, followed by two and three, the phase rotation is 1–2–3. If phase one reaches a maximum, followed by phases three and two, the phase rotation is 1–3–2. This orientation of the leads is important since a three-phase motor will run in one direction when connected 1–2–3, and in the reverse direction if connected 1–3–2. Moreover, if two generator sets are to be operated in parallel, the phase rotation of the connections must be the same for both sets, or a short circuit will occur.

The procurement documents will define the phase rotation of the terminals of the generator set being tested.

## 116.1.2 Phase Rotation Indicators

*116.1.2.1 Motor*

A three-phase ac motor with a disk or rag fastened to the shaft to indicate direction of rotation, and whose leads have been marked to show which are 1, 2, and 3, may be used. Marking the motor leads can be accomplished only by comparison with a known phase sequence.

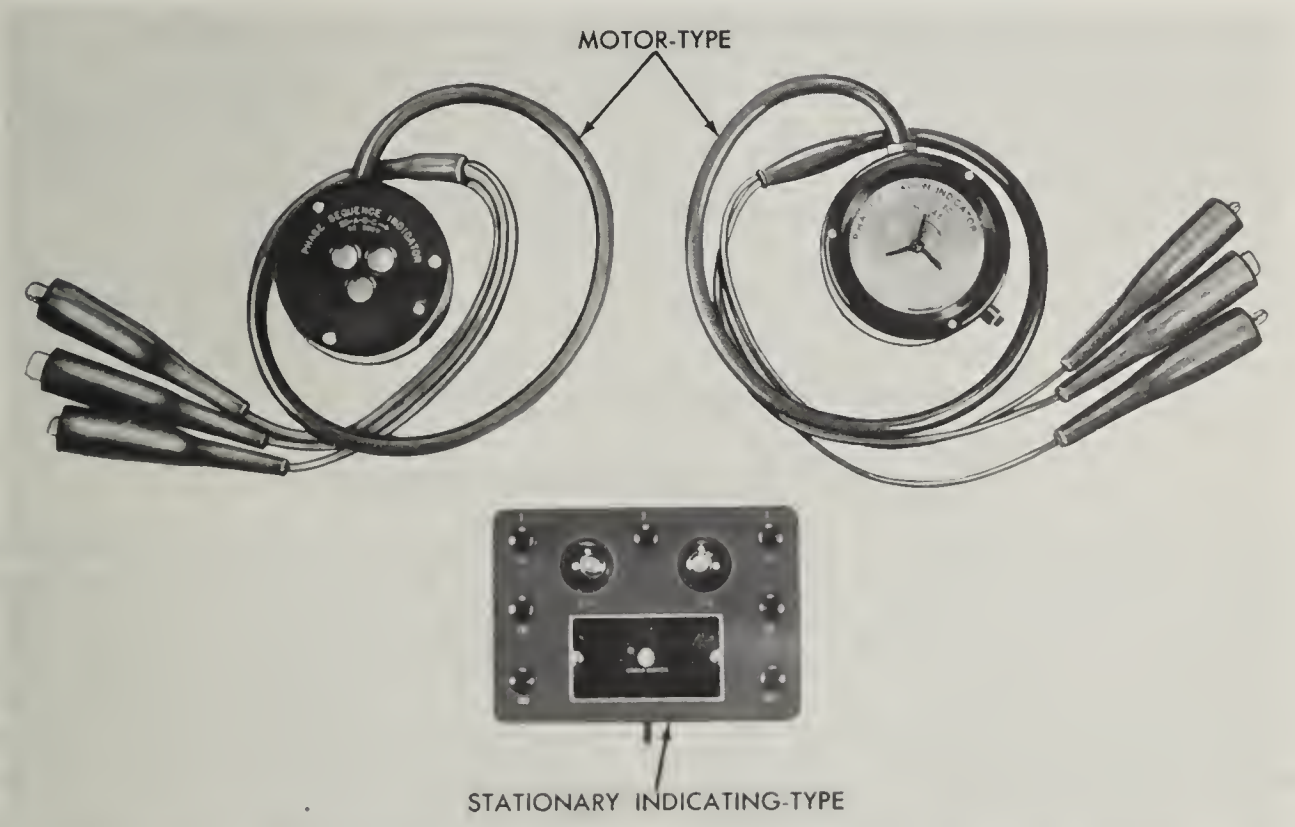



*Figure 116.1–I. Types of phase rotation indicators.*

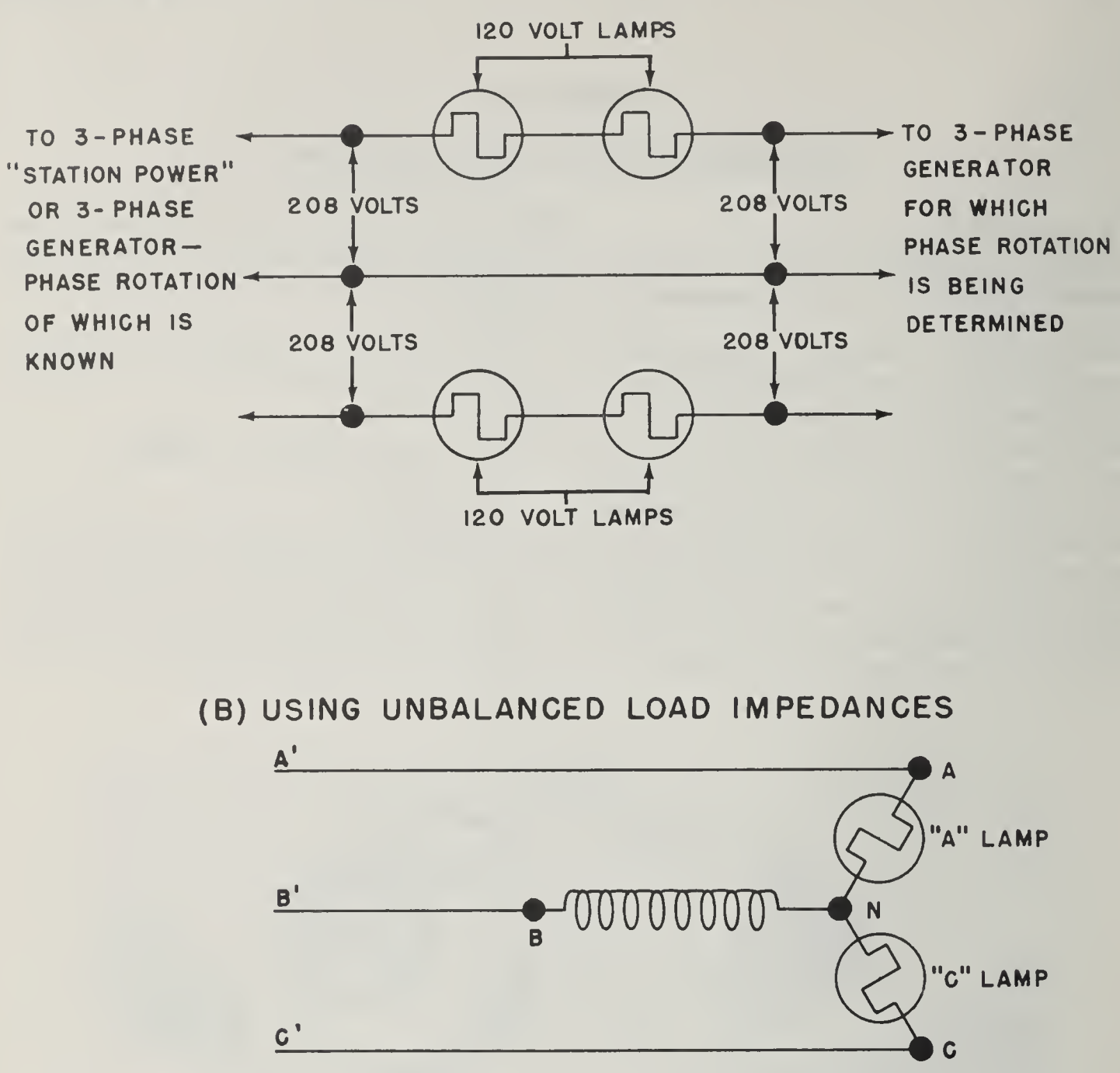



*Figure 116.1–II. Makeshift phase rotation indicators.*

*116.1.2.2 Portable Indicators*

Two types of portable indicators are available. The first type is essentially a small motor whose speed of rotation is low and whose direction of rotation is easily seen. The second type consists of an electrical circuit with two neon tubes appropriately internally connected so that one or the other will light, depending upon the phase sequence. Both these types are illustrated in figure 116.1–I.

*116.1.2.3 Makeshift Indicators*

Phase rotation may be determined by connecting two sets of two lamp bulbs in series between corresponding terminals of the test generator, and a source of three-phase voltage of the same frequency and a known phase rotation. The third terminal of the test generator shall be connected directly to the third terminal of the source (fig. 116.1–II(a)). If the phase rotation of the generator is the same as that of the source, the lamps will blink simultaneously. If the phase rotation is not the same, the lamps will blink alternately.

Phase rotation may, in general, be determined

by any set of unbalanced load impedance. One unbalanced set of load impedance consists of two lamp bulbs and an inductive reactor connected in wye (fig. 116.1–II(b)). The lamps must be similar and the reactance of the reactor should be approximately equal to the resistance value of one lamp.

The terminals of the test generator are arbitrarily marked a, b, and c, and the unbalanced load is connected as shown in figure 116.1–II. Then, if the phase rotation is ab, bc, ca, "a" lamp will be brighter than "c" lamp, and, if the phase rotation is ab, ca, bc, "c" lamp will be brighter than "a" lamp.

This can be shown by using "Kirchhoff's voltage and current laws" to make a vector analysis of the voltages applied to the lamps.

# 5. INSTRUMENTATION AND GENERAL TEST METHODS 200 SERIES

# METHOD 201.1

# ELECTRICAL INSTRUMENTATION

## 201.1.1 General

The following requirements applicable to instruments and equipment commonly used in the testing of engine generator sets shall be complied with.

## 201.1.2 Use of Instruments

The following precautions apply in general to the use of electrical instruments and those mechanical instruments, employing jewel bearings, small operating torques, or delicate movements.

Before any instrument is used, it should be inspected to determine that the pointer is free and rests at zero. No instrument should be used that sticks or binds at any part of the scale, or has a zero error.

Instruments containing permanent magnets should neither be carried through nor placed in strong magnetic fields because the accuracy of the instrument may be affected.

Cables carrying heavy currents to an instrument, or near it, should be kept close together and must never be placed on opposite sides of iron objects, especially if they are resting on an iron floor.

An instrument should read the same in each of four positions, 90° apart, if it is unaffected by stray fields.

Instruments should not be dropped, bumped against each other, or placed on tables or benches used for such work as hammering, chipping, or riveting. Steel pivots resting on jewel bearings support the moving parts of most instruments and the pressures exerted on the jewel by the pivot in such a bearing is usually of the order of several tons per square inch. For this reason, shock and vibration can easily damage jewel bearings and cause erroneous readings.

Instrument cover glasses should never be cleaned or rubbed with a dry cloth because of the danger of building up a static electric charge on the glass. If a cover glass becomes charged, it may be discharged by rubbing gently with a damp cloth, or by moistening it with the breath. In either case, no moisture should be allowed to collect inside the instrument case.

Care should be taken to avoid errors due to parallax when reading any instrument. Recording instruments should be calibrated and read on the chart paper graduations rather than on the indicator scale.

Actual instrument readings should be entered on all data sheets and all curves shall be carefully plotted. Readings should never be corrected for instrument errors, transformer ratios, or scale factors before being entered on the data sheets. When it is desirable to have true values appear on the data sheet, two columns should be used; the first for the actual instrument reading, and the second for the corrected value.

## 201.1.3 Accuracy of Instruments

Indicating laboratory-type electrical instruments referred to in this handbook, and illustrated in section 100, shall have an accuracy at least 0.5 percent of full scale for dc meters, 0.75 percent for ac meters, and 1.5 percent for wattmeters. Instruments will be selected and connected to indicate in the accurate portion of their range.

The instruments shown in figure 201.1–I are instruments designed for maintenance work or panel board indications and should not be used for acceptance testing.

## 201.1.4 Procurement Document Requirements

The following items must be specified in the individual procurement documents.

*a.* This method will be cited in order to specify accuracy of instruments.

*b.* If other than accuracy herein specified (par. 201.1.3) it shall be so stated.

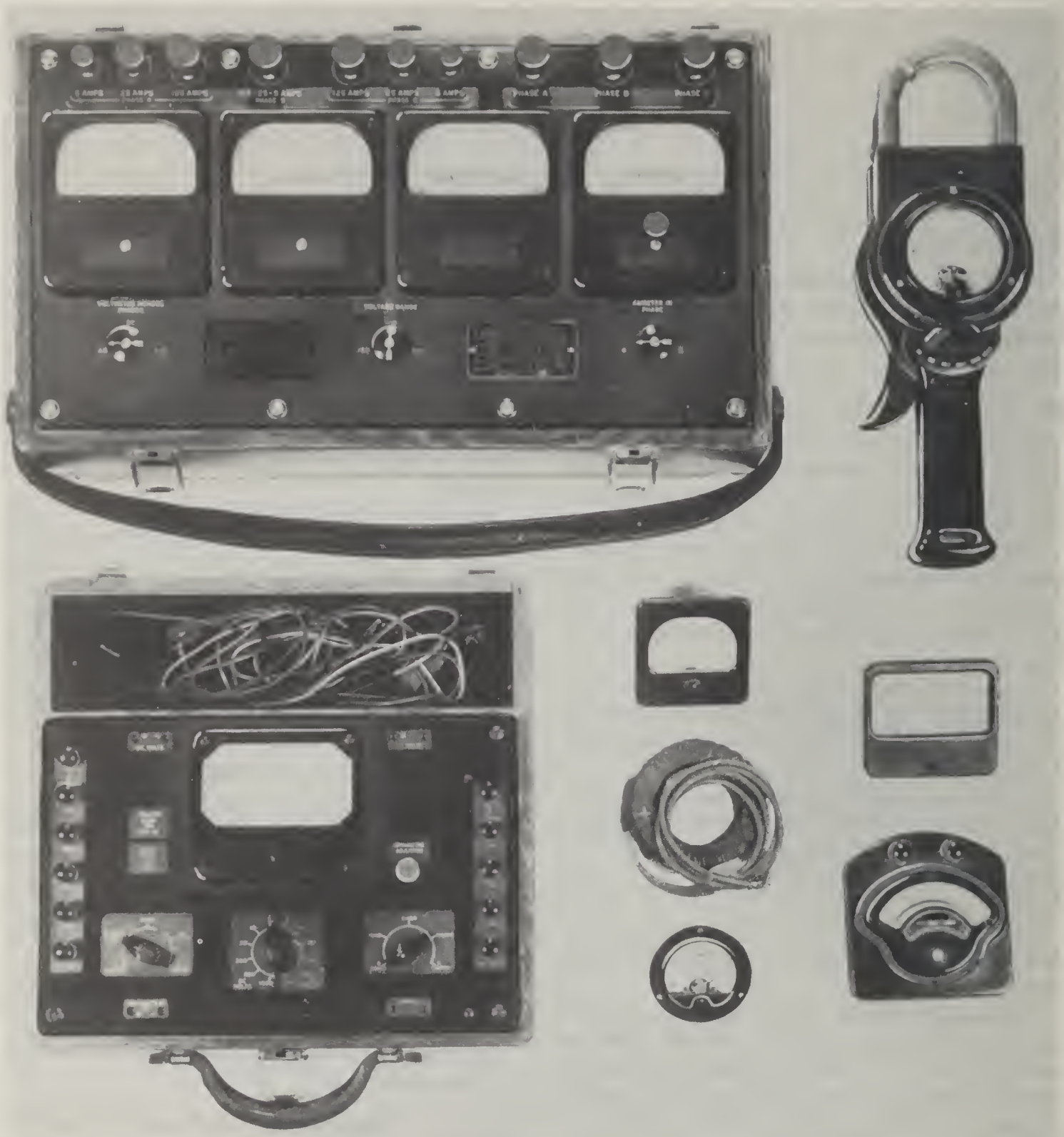


*Figure 201.1–I. Types of instruments which should not be used for acceptance testing.*

# METHOD 202.1

# THERMAL INSTRUMENTATION

## 202.1.1 General

Thermal instrumentation covers instructions for locating various measuring devices for determining temperature of components and materials, and the surrounding (ambient) air.

Usual methods for obtaining temperatures at various locations are as follows:

Generator components:
- Contact method
- Resistance method
- Embedded detector method

Engine components:
- Contact method

Ambient air:
- Contact method

Control panel:
- Contact method

Storage battery, electrolyte, and surrounding air:
- Contact method

Winterization heater:
- Contact method

Each of the above temperature measurement methods is discussed in Method 110.1.

## 202.1.2 Generator Components

*202.1.2.1 Contact Method*

The following listing gives the location and number of contact method devices to be installed before operation of the generator set.

| *Location of device* | *No. used* |
|---|---|
| Generator bearing housing or housings. | 1 (for each housing) |
| Centerline of generator frame at its uppermost part. | 2 (one at each end) |
| Stator coils at points estimated to result in highest temperature readings. | 4 (if practicable) |
| Stator core at points estimated to result in highest temperature readings. | 4 (if practicable) |
| Intake and exhaust cooling air. | 2 (at each point, if practicable) |

The following listing gives the location and number of contact method devices to be installed immediately after shutdown.

| *Location of device* | *No. used* |
|---|---|
| Collector rings | 1 each. |
| Commutator | 1. |
| Pole tips | 1. |
| Rotor windings | 1 or more. |

*202.1.2.2 Resistance Method*

This method is applicable for measuring the temperature of the generator armature, the generator field, and the exciter field. It will not be used on a rotating winding whose resistance at the ambient temperature is less than 1.0 ohm.

The application of the devices and the formula for calculating the temperature rise are given in Method 110.1.

*202.1.2.3 Embedded Detector Method*

Usually, only generator sets rated at 500-kw, or higher, are equipped with embedded detectors for determination of the temperature of the electrical windings. The temperature of stationary windings will be measured periodically by this method during a test, while that of rotating windings will be taken at standstill, immediately following shutdown.

Embedded detectors are of two types: the thermocouple type, and the resistance type. Either of these types may be employed as stationary or rotating detectors.

Before measuring temperatures by the embedded detector method, make sure that the detectors have been properly located in accordance with applicable manufacturing specifications.

*202.1.2.4 Summary of Thermal Instrumentation for Generator Components*

The following table is a summary of the thermal instrumentation methods as usually applied to the generator components:

| *Generator component* | *Method* |
|---|---|
| Armature winding of generators rated at less than 500-kw. | Contact.<br>Resistance. |
| Armature winding of generators rated 500-kw and higher. | Contact.<br>Resistance.<br>Embedded detector. |
| Insulated field windings of generators rated at less than 500-kw. | Contact.<br>Resistance. |
| Insulated field windings of generators rated at 500-kw and higher. | Contact.<br>Resistance.<br>Embedded detector. |
| Collector Rings | Contact. |
| Commutator | Contact. |
| Bearings | Contact. |
| Frames | Contact. |
| Cores and mechanical parts in contact with or adjacent to insulation. | Contact. |

## 202.1.3 Engine Components

*202.1.3.1 Engine Coolant Temperature*

Coolant temperatures will be taken on liquid-cooled engines by one thermometer or thermocouple located in the coolant outlet from the engine block, and one such device located in the circulating pump inlet, or engine block, if no pump is provided. If the engine cooling system is equipped with a bypass thermostat, make sure that the thermometer or thermocouple is located between the engine block and the thermostat.

*202.1.3.2 Lubricating Oil Temperature*

Lubricating oil temperatures will be measured by locating one thermometer or thermocouple in the oil gallery if possible, or in the sump of the oil pan. This may be accomplished through the oil filler tube, through the oil dip stick hole, or through a tapped hole in the side of the crankcase. If the engine is equipped with an oil cooler, the temperature drop across the cooler shall be measured by suitably placed thermocouples or thermometers.

*202.1.3.3 Intake Manifold Temperature*

The temperature of the intake manifold, if desired, will be taken by means of one thermometer or thermocouple inserted into the manifold through a suitable plug.

*202.1.3.4 Engine Intake Air Temperature*

The intake-air temperature will be measured by a thermometer or thermocouple placed in the entrance to the induction system. For engines equipped with scavenging air blower or superchargers, the temperature of the air on the discharge side will also be measured by a suitably placed thermocouple or thermometer.

*202.1.3.5 Exhaust Gas Temperature*

The combined exhaust temperature will be measured by a thermocouple placed in the exhaust line approximately 2 inches beyond the exhaust manifold outlet. For diesel engines, where practicable, an additional thermocouple shall be placed in the exhaust outlet of each cylinder to measure individual cylinder exhaust temperatures.

*202.1.3.6 Spark Plug Temperature*

On single-cylinder engines, the spark plug temperature will be taken by one thermocouple (gasket ured by a thermocouple placed in the exhaust line cylinder engines, the spark plug temperature will be taken under each spark plug.

*Note.* Spark plug temperatures ordinarily are taken only on air-cooled engines.

## 202.1.4 Ambient Air Temperature

*202.1.4.1 Equipment*

Ambient air temperature measurements will be made with four pairs of thermometers or thermocouples. One of these devices will be immersed and one will be exposed directly to the ambient air (fig. 202.1–I). One device of each pair is immersed to prevent it from responding to sudden or momentary temperature changes. Antifreeze will be used at low ambient temperatures, and lubricating oil will be used at normal or high ambient temperatures, in the immersion cups.

*202.1.4.2 Location*

One pair of thermometers or thermocouples will be placed approximately on a diagonal line to the generator set, at each corner of the set (fig. 202.1–II). Precautions will be taken to insure that none of the thermometers or thermocouples are located in the path of air movement due to fans or other air circulation devices. When locating the thermometers or thermocouples, they should be placed at the following distances:

| | |
|---|---|
| From floor | 3 to 6 feet. |
| From generator set | 3 feet minimum. |
| From wall or obstruction | At approximate intake air level of generator and engine. |

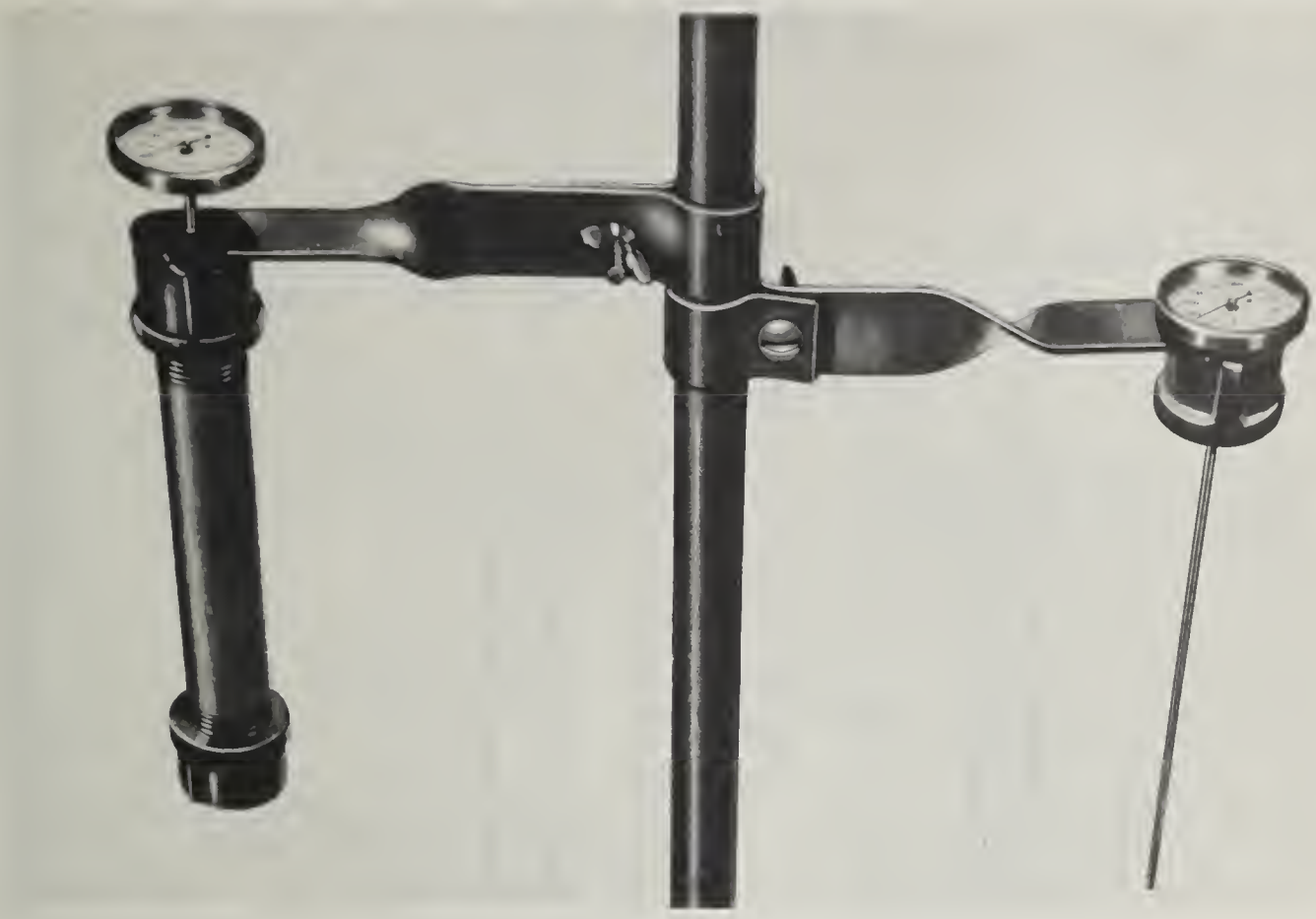


*Figure 202.1–I. Immersed and exposed thermometers.*

*202.1.4.3 Computing Ambient Air Temperature Value*

The value of ambient air temperature to be used in computing temperature rises will be the *AVERAGE* of the eight readings obtained from the thermometers or thermocouples, placed as shown in figure 202.1–II. A set of readings will be taken at three or more equal time intervals over a period of 1 hour. The average value obtained will not be acceptable for computing temperature rises if it has changed more than 5° C. during the hour.

## 202.1.5 Control Panel Temperatures

The temperature within the control panel enclosure will be taken by means of a thermocouple. The thermocouple will be mounted in the space behind the control panel and will be so located that it is surrounded only by air and is not in contact with any object. When testing a generator set on which the control panel may be opened for inspection, always close the control panel before measuring the temperature of the enclosure behind it.

## 202.1.6 Storage Battery Electrolyte, and Ambient Air Temperatures

The storage battery electrolyte temperature will be taken by a thermometer or thermocouple located in the opening to the center battery cell. For 6-, 12-, and 24-volt battery systems, the thermometers or thermocouples will be located as shown by X in figure 202.1–III. When a thermocouple is used, it will be enclosed with a corrosion resistant material which is flexible and sealed on the end in the battery. One such corrosion resistant material is "Teflon". To install the thermocouple halfway down the plates, a wooden separator about the thickness of the thermocouple can be forced down between the plates, then the thermocouple installed, then the separator pulled out. The plates will hold the thermocouple in place. If a thermometer is used, it will be located so that its bulb is completely immersed in the electrolyte. The thermocouple junction likewise will be located so that it is completely immersed in the electrolyte.

The temperature of the air within the storage

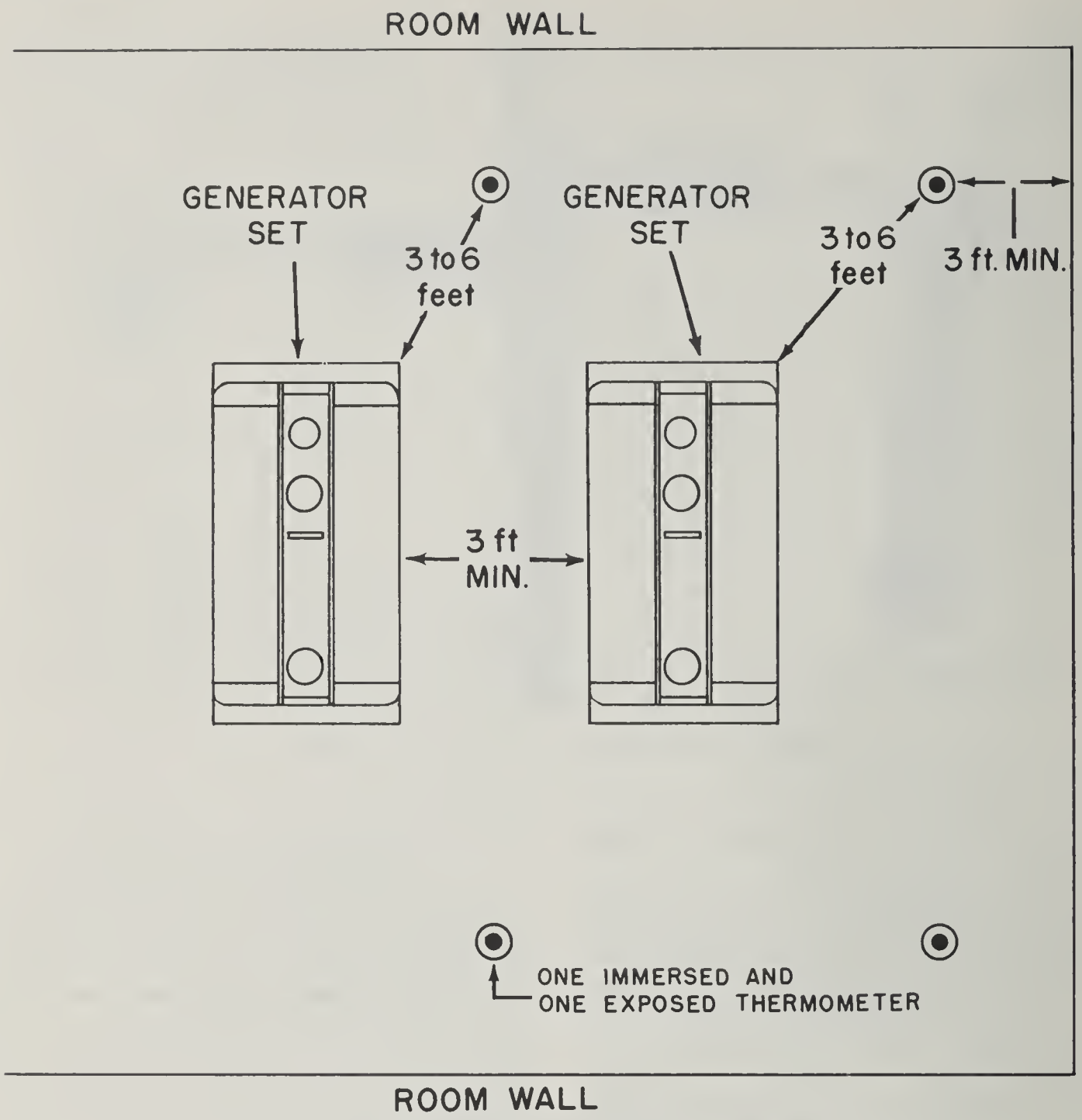



*Figure 202.1–II. Thermometer placement for measuring ambient air temperature.*

batter box will be measured by means of two thermocouples located at opposite sides of the battery box, approximately halfway up the inside wall, and free from contact with any object other than the ambient air.

### 202.1.7 Winterization Heater Temperatures

*202.1.7.1 Coolant Type Heaters*

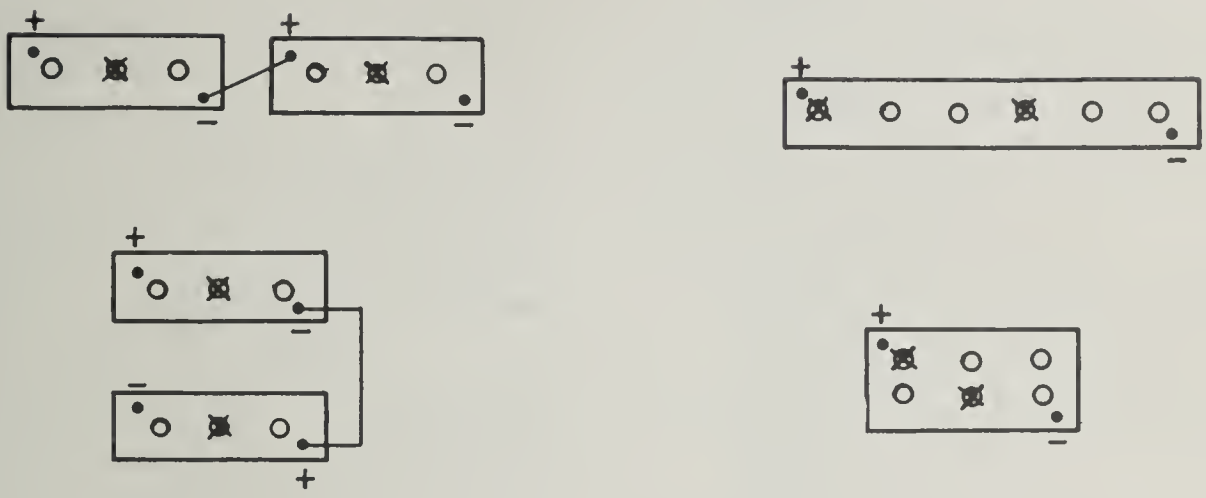
On winterization heaters which heat and circulate the engine coolant, the temperature of the coolant will be measured at its inlet and outlet to the heater. The temperature will be taken by a thermometer or thermocouple located in the piping at these points.

*202.1.7.2 Hot Air Type Heater*

On heaters which heat and circulate uncontaminated hot air, the temperature of the air will be measured at its inlet and outlet to the heater. The temperature will be taken by a thermocouple lo-

6 VOLT SYSTEMS

12 VOLT SYSTEMS



24 VOLT SYSTEMS

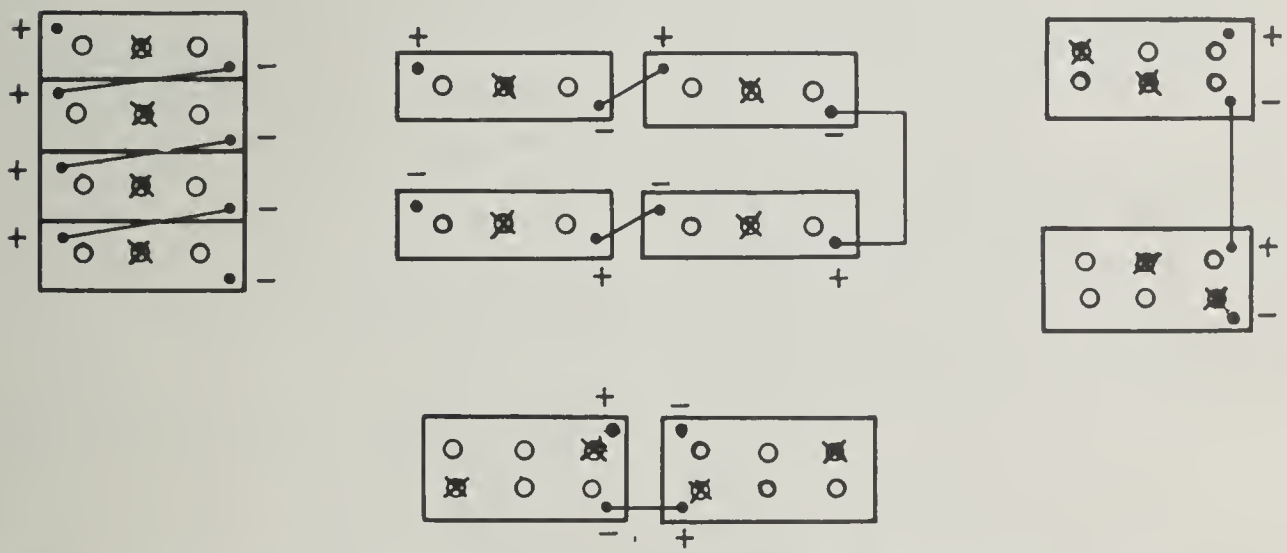


*Figure 202.1–III. Thermometers or thermocouples locations for measuring temperature of electrolyte in 6-, 12-, and 24-volt batteries.*

cated in the heater ducts at these points.

*202.1.7.3 Exhaust Gas Measurements—(Both Types of Heaters)*

The heater exhaust gas temperature will be measured by a thermometer or thermocouple located as closely as possible to the point at which the exhaust gases leave the heater. When the exhaust gas is used in heating the oil pan the temperature of the exhaust gas after passing through or over the oil pan should be measured also.

# METHOD 203.1

# DATA SHEETS

## 203.1.1 General

Tests, such as the group described in this handbook do not fulfill their purpose unless complete and accurate data are recorded.

When the data are compared directly with the requirements of the procurement documents; or when calculations are made from the information on the data sheets, and the results compared to the requirements of the procurement documents; the acceptance or rejection of the unit under test is dependent upon the data obtained.

To avoid accepting equipment which fails to meet the requirements of the procurement documents, and to be absolutely certain that any rejects fail to meet these requirements, repeat any test procedure if there is any doubt as to the accuracy of the recorded data.

Each data sheet must have a complete series of information which will identify the unit under test and the test method, in addition to the data. The following is a list of information that will be included on each data sheet:

(1) The make, rating, model number, and serial number of the unit under test.
(2) The name and number of the test method.
(3) Columns for all instrument readings, with the name and serial number of the instruments used, and the multiplying factor.
(4) The date on which the test is performed, the reading number, and the time of each reading.
(5) The names of the personnel performing the test and the Government inspector.
(6) The contract, or purchase order number, under which the unit is being tested.
(7) Notes as necessary to clarify the conditions of the test.
(8) The name or designation of the agency responsible for inspection of the unit under test. For example: "Philadelphia District—Corps of Engineers."
(9) Zero instrument readings will be recorded as such. Do not leave the space blank.

All instruments will be carefully read and these readings will be recorded directly on the data sheet. They will not be multiplied by the multiplying factor before recording.

When making readings for steady-state conditions, be certain that these conditions have been reached before recording the readings.

No erasures of readings will be made. Errors shall be neatly crossed out with a single straight line.

Complete, accurate and neat data are essential when performing the tests in this handbook.

Samples of data sheets for many test methods will be found in this handbook. It is recommended that the format of each be followed so far as possible, to facilitate the obtaining of comparative data.

# METHOD 204.1

# TEST REPORTS

## 204.1.1 General

A well-organized test report that compares the test results with the procurement document requirements, and substantiates the test results with test data and calculations, will enable anyone reviewing the test report to evaluate the engine-generator set or generator which has been tested, in a minimum time.

The test report also will give information that will enable the reviewer to determine whether or not the unit conforms to those procurement document requirements which are not covered by specific test methods, such as dimensions, weights, materials, etc.

All waivers, deviations, and other changes in the original procurement documents will be listed and fully explained in the report.

Any suggestions for modification of specifications or methods of test should be discussed and documented.

The following paragraphs briefly describe the prescribed organization and principal contents of a test report on a preproduction model.

## 204.1.2 Organization and Contents of Report

Unless otherwise specified in the procurement documents, the test report will conform with the following requirements:

*204.1.2.1 Title Page*

Each report will have a title page containing the following:

(1) Full nomenclature identifying the unit which has been tested.
(2) Contractor's name and address.
(3) Purchase order and contract number.
(4) Date on which the report is submitted.
(5) Names of authorized Government representatives who have witnessed the tests.

*204.1.2.2 Photographs*

If the unit is equipped with a housing, photographs of the unit with all doors open and with all doors closed will be included in the report. Make sure that at least one of the photographs shows a closeup of the control panel.

*204.1.2.3 Table of Contents*

Each report will have a table of contents similar to the following:

### TABLE OF CONTENTS

Page

SECTION I. INTRODUCTION
II. ABSTRACT
Identification
Conclusions
Recommendations
III. WAIVERS, DEVIATIONS, MWO'S, ETC
IV. INVESTIGATION
Equipment identification
Test results
Deficiencies
Maintenance requirements
Requirements not covered by test methods

TABLE OF CONTENTS—Continued

Page

V. DISCUSSION
Conformance to military characteristics
Compliance with procurement description
VI. CONCLUSIONS AND RECOMMENDATIONS
Conclusions
Recommendations
APPENDIX A
Data sheets
APPENDIX B
Characteristic curves
Recording meter charts
Oscillograms

*204.1.2.4. Introduction*

The introduction will include—

(1) A statement giving the scope of the report (what tests are being reported), complete nomenclature identifying the equipment, the equipment and test specification numbers under which the unit is being manufactured, and the purchase order and contract numbers.

(2) The names of the test engineers who performed and directed the tests.

(3) The names of other personnel witnessing tests and their affiliation.

(4) The duration of the tests in hours, starting and completion dates, and test site locations.

*204.1.2.5 Abstract*

The abstract is prepared by the authorized Government representative and includes—

(1) Statement by the authorized Government representative as to the coverage of the tests performed on the unit. *Example:* "This report covers preproduction tests on a 5–KW, 60-cycle, ac engine-generator set, Model XYZ, manufactured by Gloworm Incorporated of Chester, Pennsylvania, under contract number DA–11–184–ENG–1048 and Purchase Order No. 88F12345–29."

(2) Conclusions of the authorized Government representative as to the acceptability of the unit. *Example:* "It is concluded that the engine-generator set meets (or, does not meet) the requirements of the specifications and other procurement documents, without exceptions (or, with the following exceptions)."

(3) Authorized Government representative's recommendations. *Example:* "It is recommended that the Gloworm Company proceed with (or, modify the unit as recommended before proceeding with) production of these engine-generator sets, in the quantities called for in the contract." If it is believed that specific additional tests are required, so state.

(4) Recommended changes in the language of future specifications.

(5) Specific changes recommended in contract requirements.

(6) Authorized Government representative's signature, followed by his title and the name of his district.

*204.1.2.6 Background*

1. Authority.

*a.* Reference to directives, pertinent contract provisions and any letters of instruction.

*b.* All waivers, deviations, and other changes in the original procurement documents will be listed and fully explained in this part of the report. The explanations should include the authority responsible for such waivers, deviations, etc.

2. History.

*a.* Summarize past tests under same contract and any similar history which makes report more understandable.

TABLE I

EQUIPMENT IDENTIFICATION

Date_____

Unit_____
Manufacturer_____
Model No._____ Serial No._____

| ENGINE | | | | GENERATOR | | | |
|---|---|---|---|---|---|---|---|
| Unit_____ | | | | Unit_____ | | | |
| Mfgr._____ | | | | Mfgr._____ | | | |
| Serial No._____ | | | | Serial No._____ | | | |
| Type_____ | Model_____ | | | Type_____ | | | |
| HP_____ | Speed_____ | | | Model_____ | | | |
| Fuel_____ | No. Cyl._____ | | | KW_____ | | Speed_____ | |
| Bore_____ | Stroke_____ | | | KWA._____ | | Freq._____ | |
| Displacement_____ | | | | Volts_____ | | Amps_____ | |
| Firing Order_____ | | | | P.F._____ | | Phase_____ | |
| Compression Ratio_____ | | | | | | | |

| | Weight, dry (lb.) | Length | Width | Height |
|---|---|---|---|---|
| Crated | _____ | _____ | _____ | _____ |
| Uncrated | _____ | _____ | _____ | _____ |

CAPACITY

Coolant_____ Oil_____ Fuel_____

REMARKS: State whether or not set is winterized model

_____

_____

_____

_____

RECORDER_____

_____

*Figure 204.1-I. Equipment identification table (sheet 1).*

TABLE I (Cont'd)

EQUIPMENT IDENTIFICATION

Date _____ Project No. _____

Unit _____
Manufacturer _____
Model _____ Serial No. _____

COMPONENT

Voltmeter _____
Ammeter _____
Freq. Meter _____
Wattmeter _____
Voltage Regulator _____
Carburetor _____
Governor _____
Spark Plug _____
Magneto _____
Air Cleaner _____
Radiator _____
Overload Trip _____
Overspeed Trip _____
Underspeed Trip _____
Overtemp. Trip _____
Oil Filter _____
Fuel Pump _____
Fan Belt _____
Governor Belt _____
Fuel Filter _____
Batt. Charging Gen. _____
Batt. Charging Reg. _____
Batt. Charging Ammeter _____
Oil Pressure Gage _____
Water Temp. Gage _____
Contactor _____
Radio Suppression Components _____
Rheostats _____
Switches _____
Winterization _____
Starting Motor _____

REMARKS: _____

_____

_____

RECORDER _____

_____

*Figure 204.1–II. Equipment identification table (sheet 2).*

*b.* List any MWO's on past sets which have been considered in the construction of the new model.

*204.1.2.7 Investigation*

This part of the report will include—

(1) A table of contents of the section.

(2) Table I, Equipment Identification (figs. 204.1–I and 204.1–II). The first table, figure 204.1–I, is self-explanatory. The second table, figure 204.1–II, provides space for writing in after each component, the name of its manufacturer, its model and serial numbers, and its range or rated capacity.

(3) Table II. Test Results. The table shown in figure 204.1–III will be used to tabulate the method number, description of the procurement document requirements, test results, and compliance with procurement requirements. All test methods will be covered on sheets of this form.

(4) Table III. Deficiencies. This table, the form for which is shown in figure 204.1–IV, will contain all deficiencies noted during the tests, the manner in which the deficiency was eliminated, and any remarks concerning the deficiency which may be pertinent. Engine and engine accessory deficiencies, generator and generator accessory deficiencies, and deficiencies of all other components will be treated by separate groups.

(5) Table IV. Maintenance. This table, the form for which is shown in figure 204.1–V, will contain a list of all maintenance operations performed on the equipment during the tests. The information will be treated in the same three separate categories as in Table III.

(6) Requirements not covered by test methods. This part of the report will give information that will enable the reviewer to determine whether or not the unit conforms to those procurement document requirements which are not covered by specific test methods, such as dimensions, weights, materials, etc. This information may be given in tabular form wherein the requirements will be listed in one column and the characteristics of the unit being tested in a second column. Remarks or recommendations may be listed in a third column.

*204.1.2.8 Discussion*

This part of the report shall contain—

(1) A discussion of the unit under test as to its conformance to military characteristics. This discussion should be comprehensive and may cover those desirable characteristics of the unit which are beyond the requirements of the procurement documents but which may be useful to the reviewer in making a complete evaluation of the unit. *Example:* "This set conforms to the military requirements for a gasoline-powered engine-generator set capable of operating 1,000 hours without major overhaul, and able to deliver name plate power after such time, at an elevation of 5,000 feet. It is capable of operating in the temperature range of −65° F. to 125° F., and is storable without damage in a temperature range of −85° F. to 165° F. The generator set is well made, of good materials, and its overall design is such as to permit easy maintenance in the field. Four different voltage connections are provided, making the generator set a very flexible general-purpose unit."

(2) A discussion of the unit under test as to its compliance with specifications, including authorized waivers, deviations, and changes. *Example:* "The preproduction model conforms to all of the requirements of the basic specification MIL–G–10285, dated 15 August 52, and the referenced engine specifications MIL–E–11275B, dated 15 Apr 55. All high mortality engine parts are constructed in accordance with the applicable standards." Point out deficiencies in compliance with terms of contract. If it is considered advisable that any of the requirements of the contract be changed, show why and indicate whether credit will be due the Government from the Contractor. Discuss desirability of changes in specifications for future procurement.

TABLE II

TEST RESULTS

Manufacturer GLOWORM, INC.

Model Number 42 J

Serial Number 196

Generator Rating 30-KW, 400 CPS
120/208 - 240/416 volts

Contract No. 29-1492-29

Date 22 August 52

Test Engineers Smith
Jones

| Method Number | Method Title, Description of the Procurement Document Requirements, and Test Conditions | Procurement Requirement | Test Results | Compliance with Procurement Document Requirement |
|---|---|---|---|---|
| 601.1 | Voltage waveform (oscillographic | | | |
| | Waveform deviation factor | Not to exceed 5% | | |
| | a. Line-to-line | | | |
| | (1) Open circuit | 5 % | 1 % | yes |
| | (2) Full load - 1.0 PF | 5 % | 1.3 % | yes |
| | b. Line-to-neutral | | | |
| | (1) Open circuit | 5 % | 1.1 % | yes |
| | (2) Full load - 1.0 PF | 5 % | 3 % | yes |
| | | | | |
| 507.1 | Phase rotation | 1 - 2 - 3 | 1 - 2 - 3 | yes |
| | | | | |
| 514.1 | Under frequency protective device test | | | |
| | | Breaker must trip when | 365 CPS | yes |
| | | frequency falls to | | |
| | | 360 cycles per second | | |
| | | but not above 375 | | |
| | | cycles per second. | | |
| | | | | |

Gov't. Inspector John Doe

Sheet ___ of ___ Sheets

*Figure 204.1-III. Sample sheet of Table II, Test Results.*

TABLE III

Deficiencies

(Use this space to identify the component group, such as "Engine and Engine Accessories".

Page

| Item | Deficiency | Remedy | Remarks |
|---|---|---|---|
| | | | |

*Figure 204.1–IV. Form for table of deficiencies.*

TABLE IV

Maintenance Requirements During Test Page

Use this space to identify
the component group, such as
"Engine and Engine Accessories".

| Item | Maintenance Requirement | Remarks |
|---|---|---|
| | | |

*Figure 204.1-V. Form for table of Maintenance Operations.*

*204.1.2.9 Conclusions and Recommendations*

This part of the report will contain the conclusions and recommendations of the contractor and will include—

(1) Conclusions. *Example:* "This preproduction model has met the specific requirements, as well as the general intent, of the specifications and has evidenced that it has the desired military characteristics."

(2) Recommendations. *Example:* "It is recommended that this design be followed exactly in the production models and that construction of these units proceed immediately."

(3) Signature and title of the person within the contractor's organization who is authorized to make the above conclusions and recommendations.

*204.1.2.10 Appendix A*

Pages of appendix will be consecutively numbered to facilitate reference. This appendix shall contain—

(1) A table of its contents, including test method number, date of test, and appendix page number.

(2) The data sheets required by each test method for all tests prescribed by the procurement documents. These data sheets will be arranged in the order in which the tests were performed. All tabulations of test results will immediately follow the pertinent data sheet.

(3) The actual plotted curves which are required by the pertinent test methods. These curves will be clearly identified with the method title and description of the curve.

(4) References to recording meter charts and oscillograms which are required by pertinent tests but which are included in Appendix B because of their bulk.

*204.1.2.11 Appendix B*

This appendix shall contain—

(1) A table of its contents.

(2) The recording meter charts required by the pertinent tests. These charts will be folded and bound within the report in such manner that they can be easily unfolded and read without being torn or misplaced.

(3) The oscillograms required by the pertinent tests. These oscillograms will be folded and bound within the report in such manner that they can be easily unfolded and read without being torn or misplaced.

# METHOD 205.1

# GENERAL INSTRUCTIONS FOR CONNECTING TESTING INSTRUMENTS

## 205.1.1 General

Even though the most precise instruments are used to determine the quantitative value of effects occurring during tests, if the apparatus is faultily connected, the resulting data will be either completely useless, or qualitative at best.

In the following pages are schematic diagrams indicating the methods of connecting the most commonly used instruments required for the tests covered by this handbook.

It is recognized that the terminal posts of all instruments are not in the same place as those shown in the diagrams and, therefore, judgment must be exercised in the connection of any specific instrument. The manufacturer's instructions should always be consulted in case of doubt as to the proper utilization of any test apparatus.

Where complicated instrumentation is required by a test method, circuit diagrams are included in the individual method.

Indicating instruments have been shown in most of the diagrams. Where recording instruments are required, they may be connected into the circuit in the same manner as shown for indicating instruments.

The general theory of operation of the instruments shown on the diagram is covered in the 100 series of Methods of this handbook.

## 205.1.2 Calibration of Instrument

Instruments should be calibrated periodically in order to insure their accuracy. They should always be calibrated before an extensive testing program is begun. Standard instruments used in calibration should have at least five times the accuracy of the instrument to be calibrated. Calibrated reference instruments of lesser accuracy than standard, which are not used for any other purpose, may be used for the required periodic check of test instruments.

Instruments should be calibrated at the frequencies at which they are going to be used.

## 205.1.3 Selection of Instruments

Before connecting instruments into circuits, thought should be given to the range of readings which will be required. The range of the instrument should be great enough so that it will not be burned out during normal use, but the range should not be so great that the readings will be so low on the scale as to make the accuracy of readings unreliable. On dc instruments, readings normally should not be made on the lower 15 percent of the scale. On ac instruments, the readings should not be made on the lower one-third of the scale.

Some instruments have leads which are calibrated for use with those particular instruments. Those instruments always should be used with the leads provided or the calibrations will be useless.

Some instruments have ON-OFF holddown buttons on their cases. These instruments usually are designed for intermittent use and should not be connected into live circuits with the buttons taped down so that the meters read continuously. Serious overheating and possible destruction of the instrument may occur if this precaution is ignored.

Care should be taken to keep unshielded instruments out of the stray fields of power circuits.

## 205.1.4 Voltmeters

Since voltmeters are potential measuring devices, they are placed "across the line" in use. Care in selection of voltmeters is necessary since these instruments consume power in operation. Where measurement of potential of high impedance or high resistance circuits is required, high resistance and, therefore, low circuit drain, instruments must be used or the instrument power may disturb the basic circuit.

*205.1.4.1 Ac Voltmeters*

Figure 205.1–I shows the method of connecting an ac voltmeter so as to measure the potential between two wires. Care in selection of the proper range should be exercised. When in doubt, use

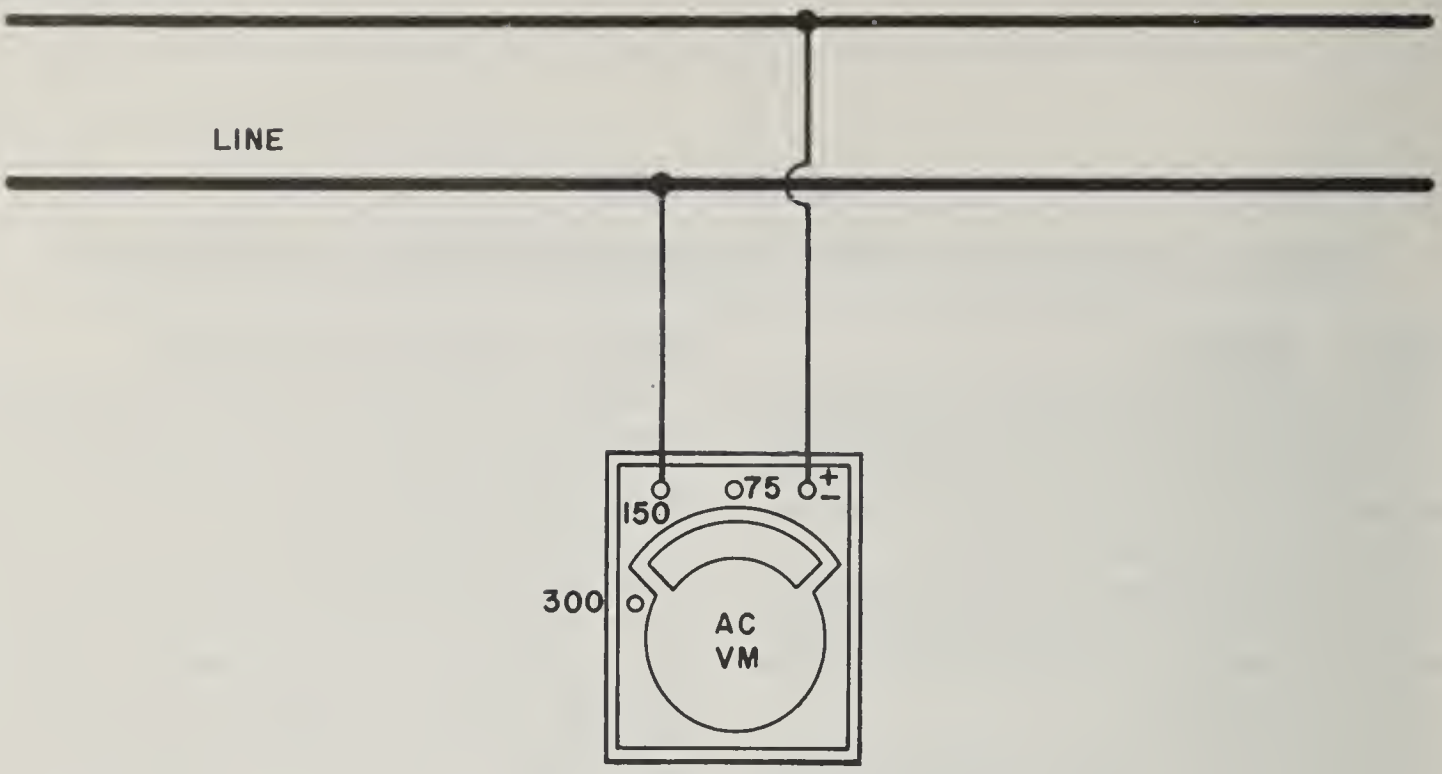



*Figure 205.1–I. Self-contained ac voltmeter.*

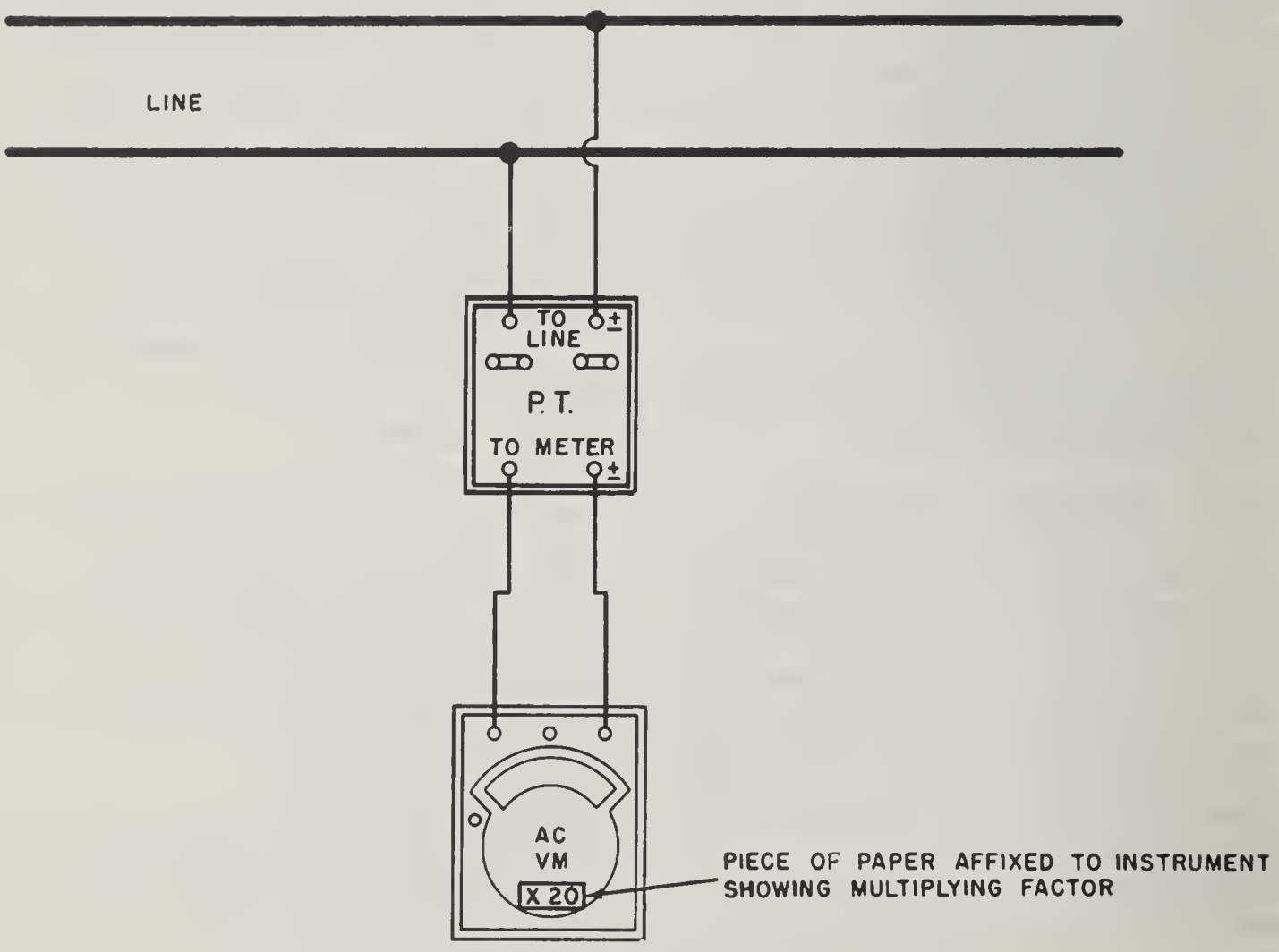



*Figure 205.1–II. Ac voltmeter with potential transformer.*

the highest range instrument available just to approximate the range needed for the measurement.

When the range of the available voltmeter is not adequate for the potential to be measured, or when instrument isolation is required, a potential transformer may be used. Figure 205.1–II shows the connection diagram for such a combination. When a potential transformer is used, a piece of paper with the multiplying factor, resulting from the transformer ratio, should be affixed to the indicating instrument. More than one instrument may be connected to one potential transformer, but the rated burden of the transformer should not be exceeded.

In some instances, the range of an ac voltmeter may be extended by the use of a multiplier which is a noninductively wound calibrated resistor. Figure 205.1–III indicates the method of connecting such a range-extending device.

When numerous readings of the potential of different circuits must be made, it is recommended that a switching device be used to facilitate the use of a single voltmeter. Figure 205.1–IV shows a schematic wiring diagram of such a switch. Note that the switch points must be of the nonshorting type. Figure 205.1–V shows a selector switch, fabricated from easily obtained materials, which might be used to read all six voltages of a three-phase, four-wire system, with one voltmeter.

When recording meters are used, the clock drive preferably should be connected to a stable source of power, such as the public utility supply, so as to eliminate paper-speed changes during operation (fig. 205.1–VI). When multiple recording units are used to measure different values their clock devices should be connected to the same power supply. When mechanical clocks are used as drives, it is desirable to use mechanical ties between the meters so that the paper speeds will be the same.

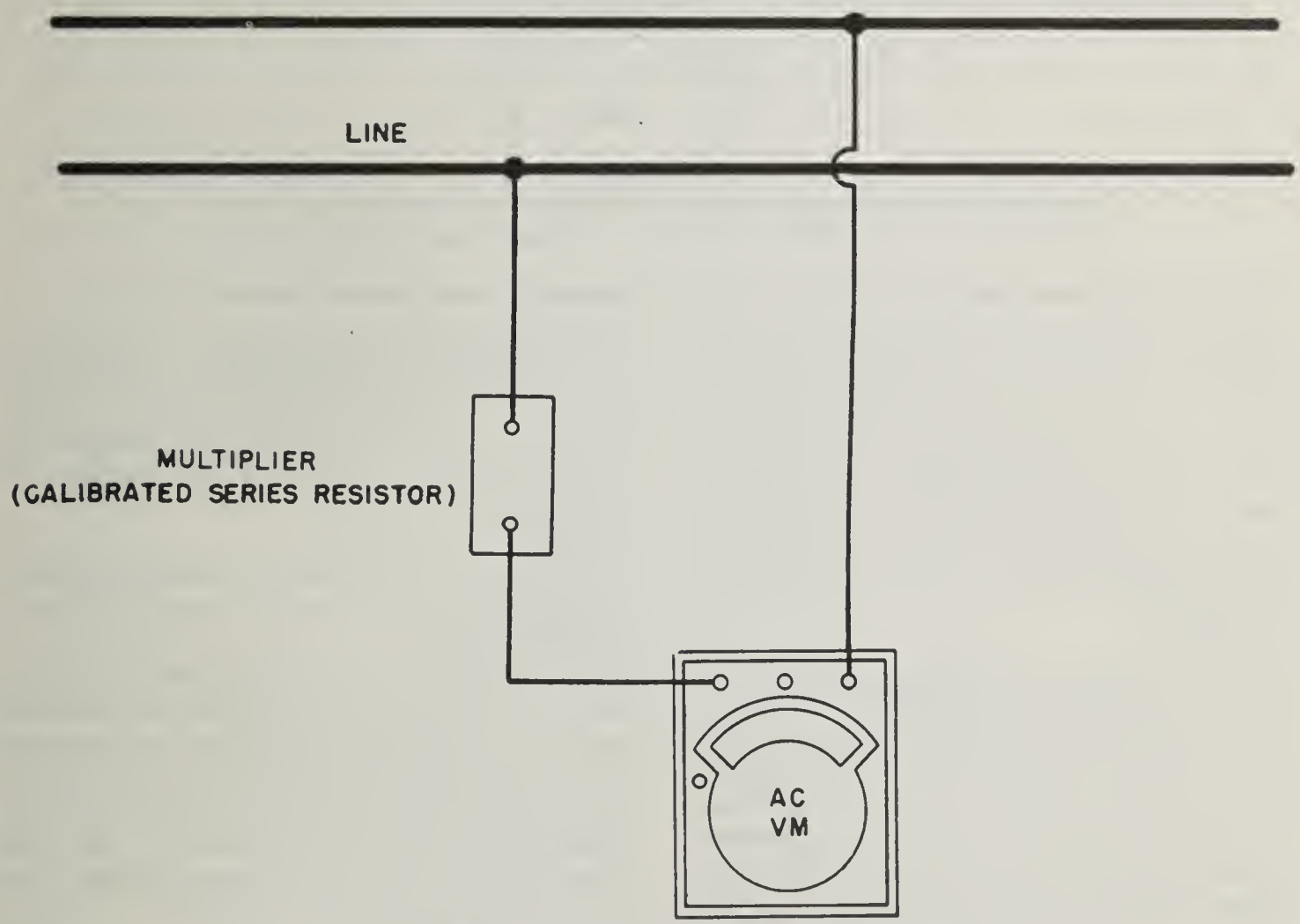



*Figure 205.1–III. Ac voltmeter with multiplier.*

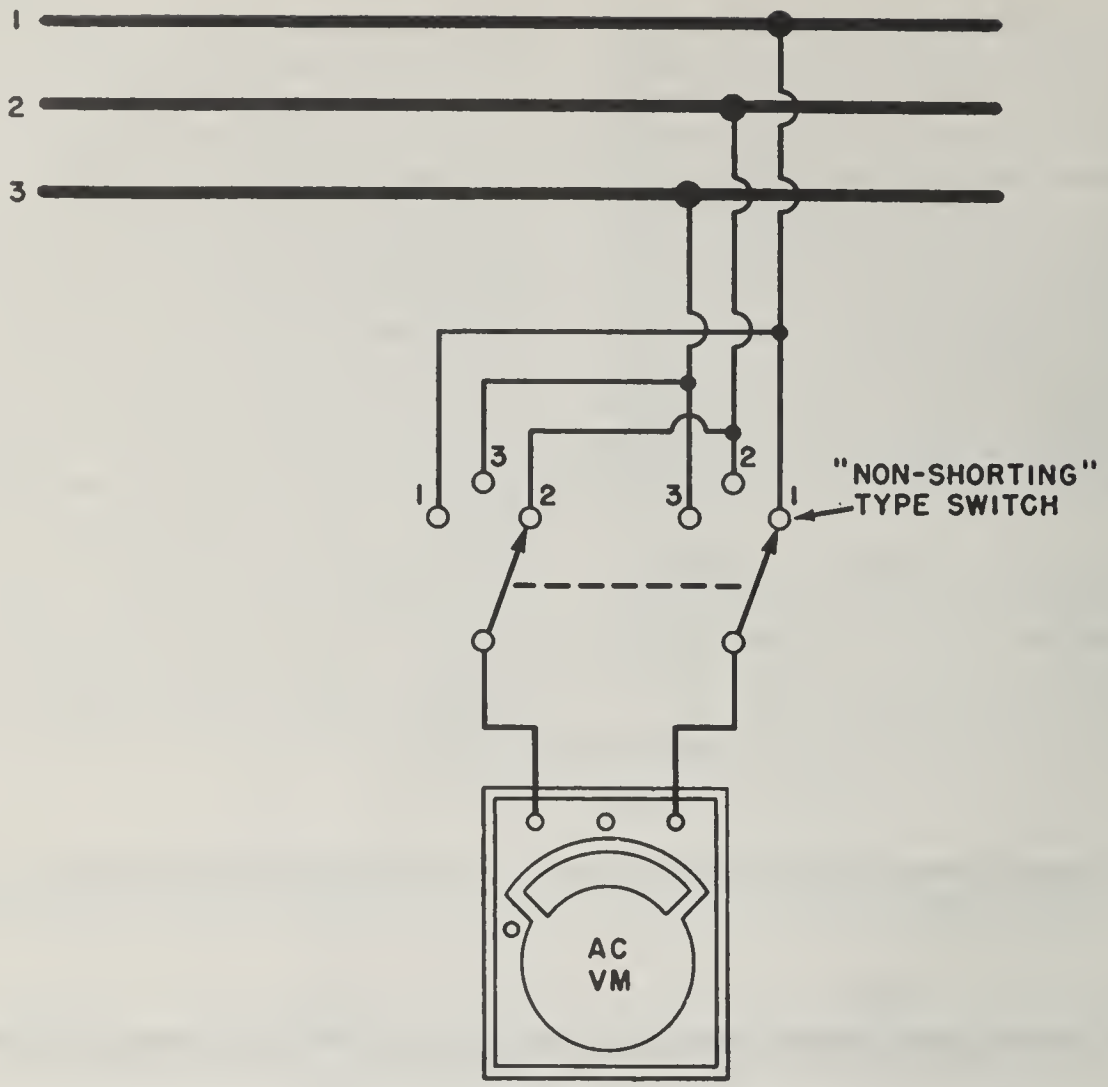



*Figure 205.1–IV. Schematic diagram of voltmeter with selector switch.*

*205.1.4.2 Dc Voltmeters*

Figure 205.1–VII shows the hookup of a self-contained dc voltmeter. It should be noted that polarity is important when D'Arsonval instruments are used. When extreme accuracy is required, such as during calibration, and a dynamometer-type instrument is used, readings should be taken with the leads direct and reversed and the result should be taken to be the average of the two readings.

Most of the notes contained in paragraph 205.1.4.1 (ac voltmeters) apply to dc instruments, but it should be noted that potential transformers cannot be used to extend the range of dc instruments. Transfer switches are more complicated since polarity must be correct for all connections.

In the measurement of dc voltages which have a ripple content, D'Arsonval instrument readings shall be considered to be the desired values.

## 205.1.5 Ammeters

Since ammeters are current measuring devices, they are placed "in the line" and never "across the line" in use. When ammeters are used they should be protected by short-circuiting switches so that transient current surges will not damage the instrument.

*205.1.5.1 Ac Ammeters*

Figure 205.1–VIII shows the hookup of a self-contained ac ammeter with a protective short-circuiting switch.

When the range of the instrument is not adequate, current transformers may be used to extend the range. The most commonly used current transformers have a five-ampere instrument side and multiple taps for the line side (fig. 205.1–IX). Where the line current is greater than the taps provided for, turns may be passed through the core of the transformer, as shown in figure 205.1–X.

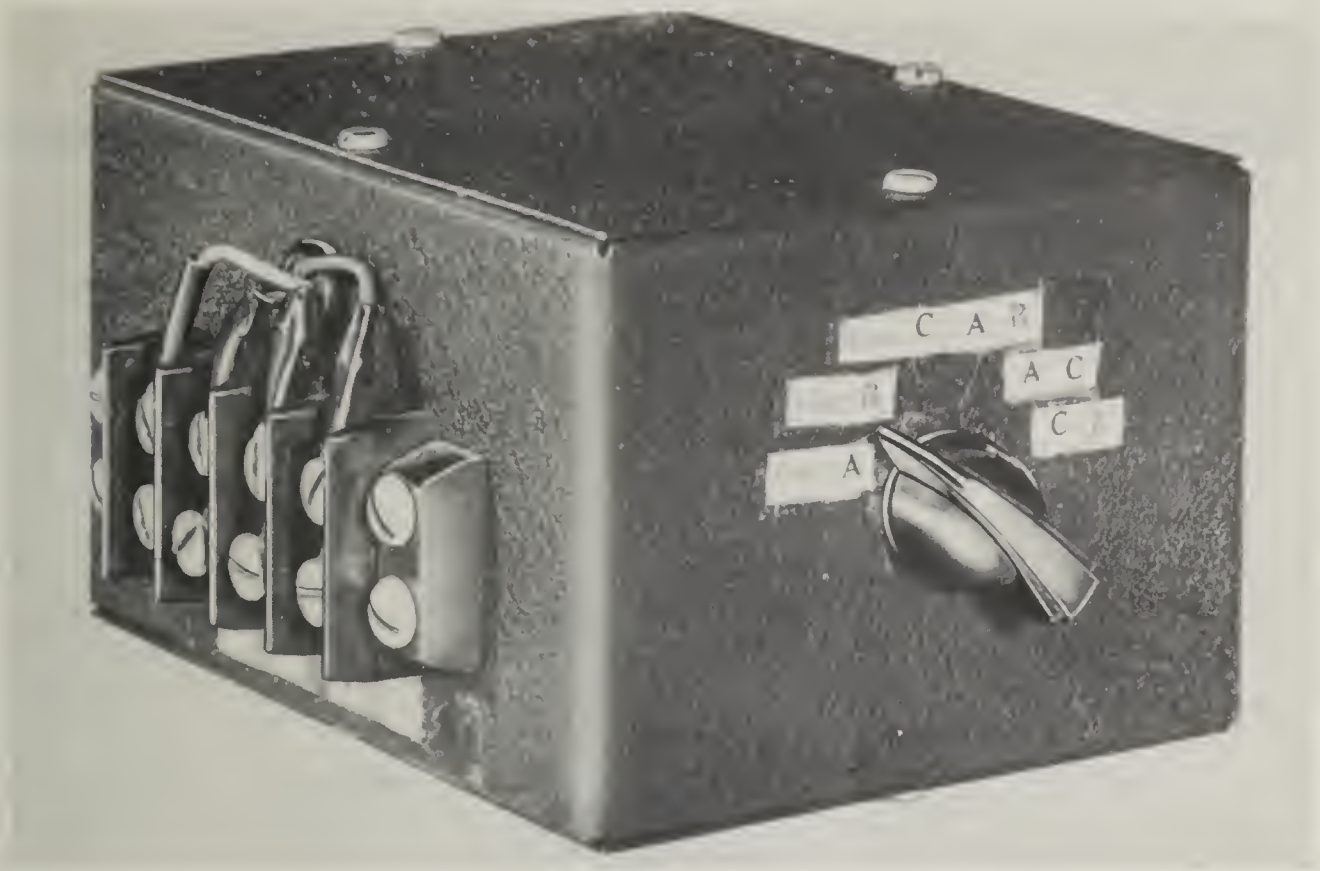



*Figure 205.1–V. Potential selector switch.*

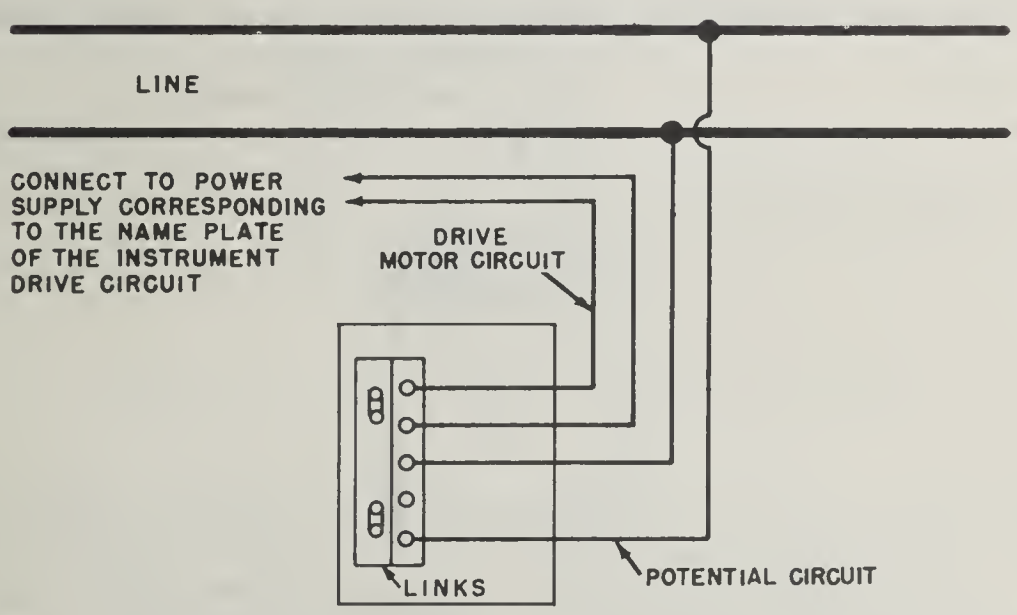

LINE
CONNECT TO POWER SUPPLY CORRESPONDING TO THE NAME PLATE OF THE INSTRUMENT DRIVE CIRCUIT
DRIVE MOTOR CIRCUIT
LINKS
POTENTIAL CIRCUIT

*Figure 205.1–VI. Recording instrument with electric drive.*

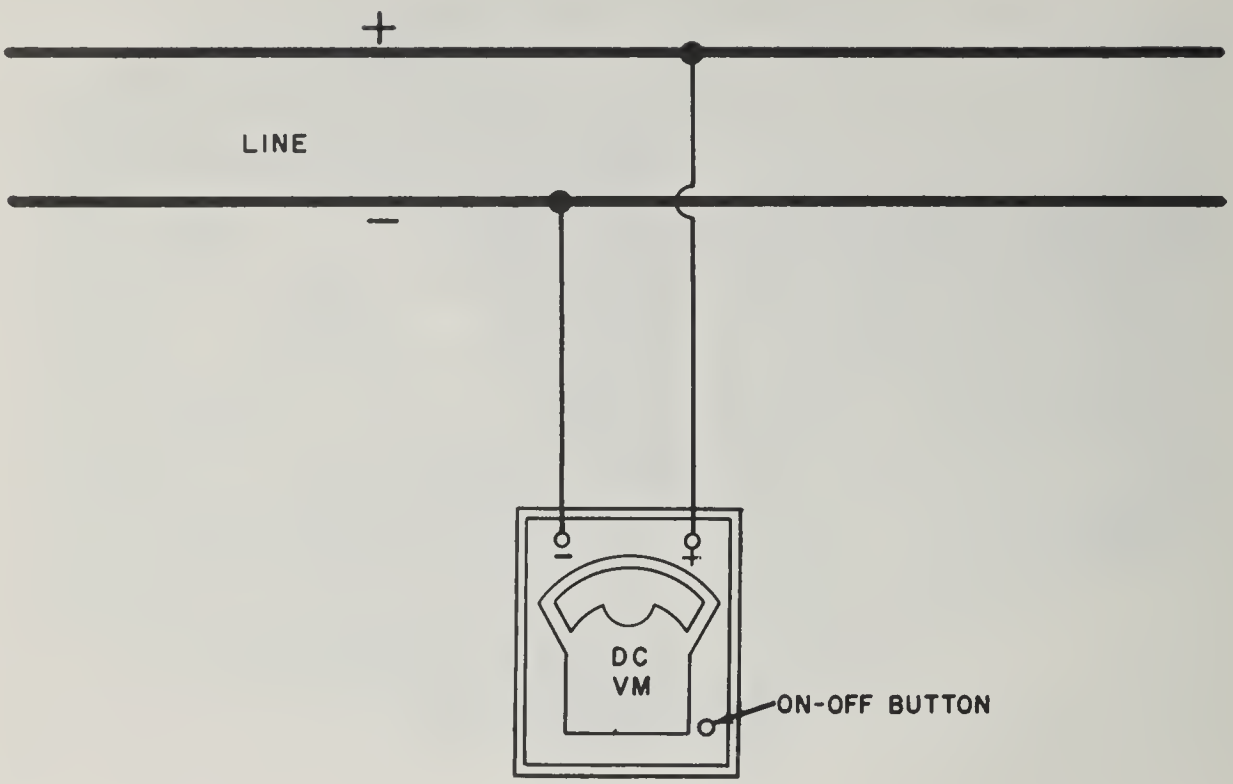



*Figure 205.1–VII. Self-contained dc voltmeter.*

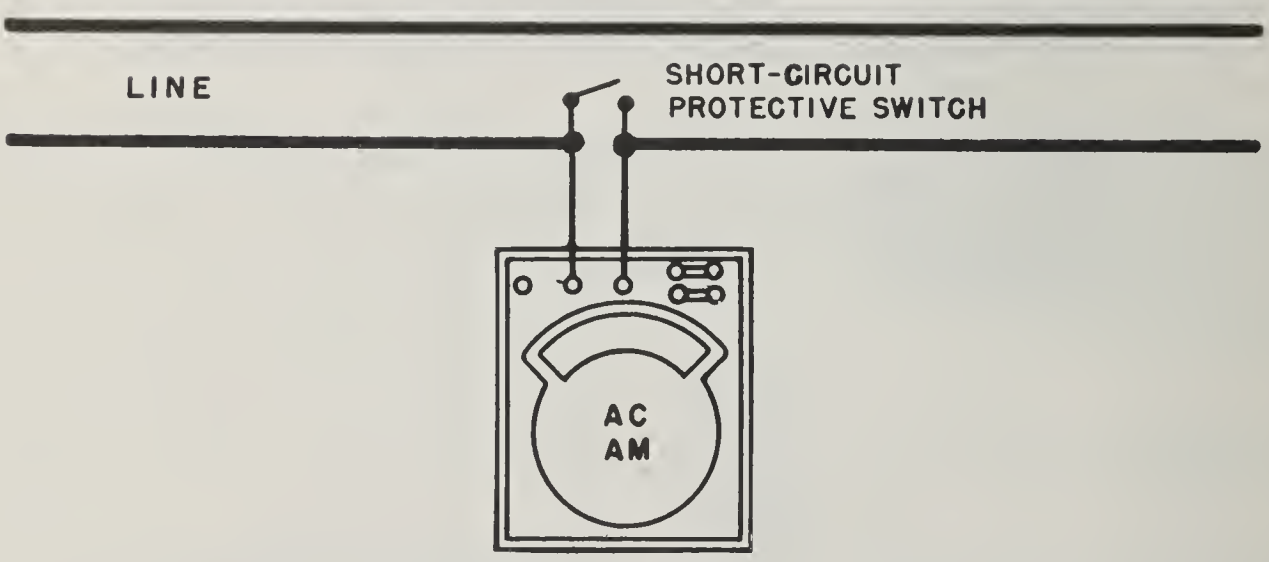



*Figure 205.1–VIII. Self-contained ac ammeter with protective switch.*

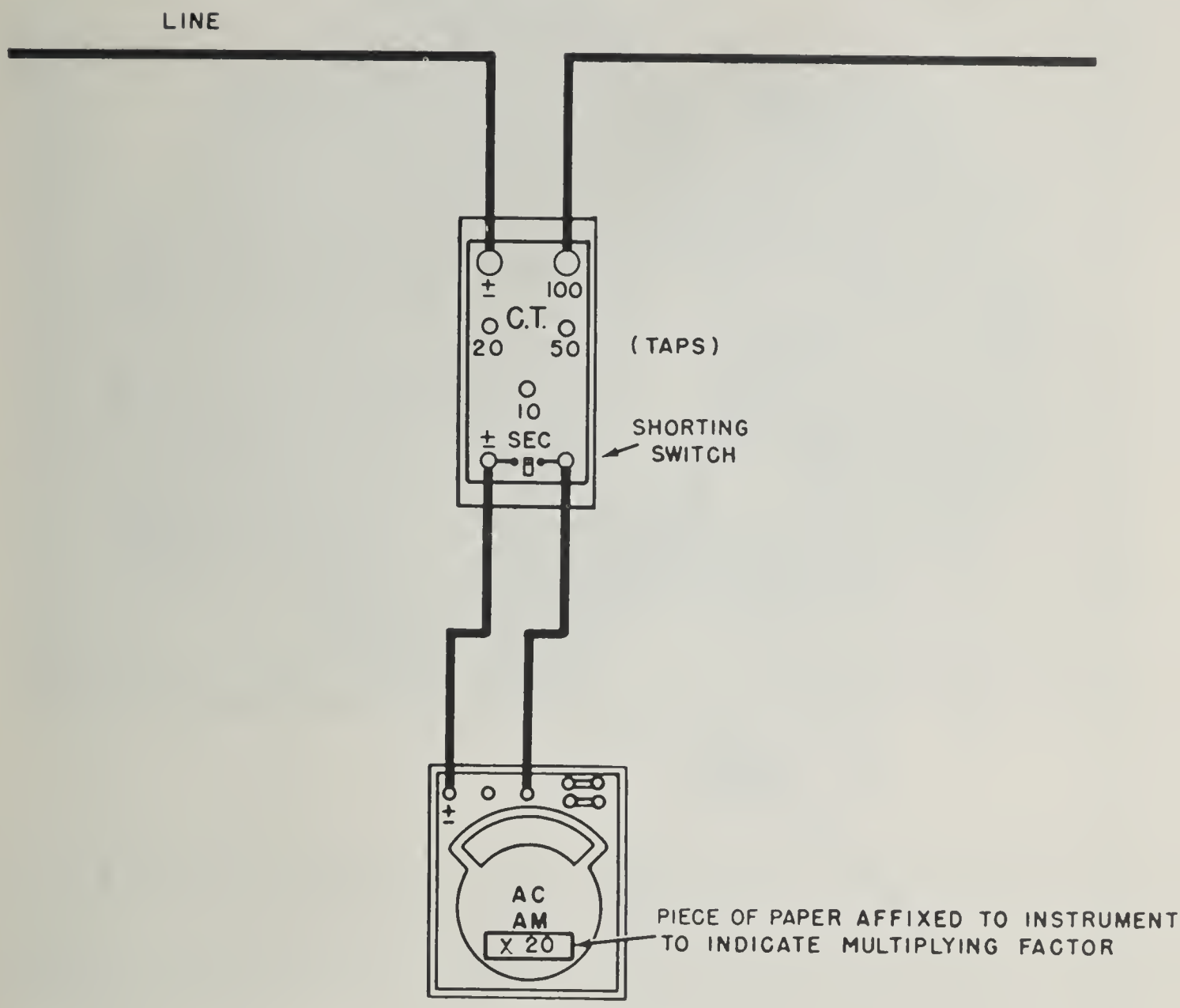



*Figure 205.1–IX. Ac ammeter with current transformer using taps.*

When multiple readings of several line currents are required, it usually is preferable to use a transfer switch, such is shown in figure 205.1–XI. This can be obtained readily since most generator sets are equipped with such a device. The hookup for a three-wire selector switch with current transformer is shown in figure 205.1–XII. It should be noted that at any position, the selector switch must short the current transformers not in use in that position. Moreover, when turned, it must short out all of the transformers before changing the position of the ammeter in the circuit. Because of the difficulties of switching without causing line-to-line shorts, ammeters without current transformers are seldom switched.

*205.1.5.2 Dc Ammeters*

Figure 205.1–XIII shows the hookup for a self-contained dc ammeter having three ranges. It should be noted that a shorting switch is desirable across the instrument to protect it from transient surges of current. Figure 205.1–XIV illustrates the wiring of a dc ammeter with a shunt. The instrument is essentially a millivoltmeter which measures the drop across a known resistance (the

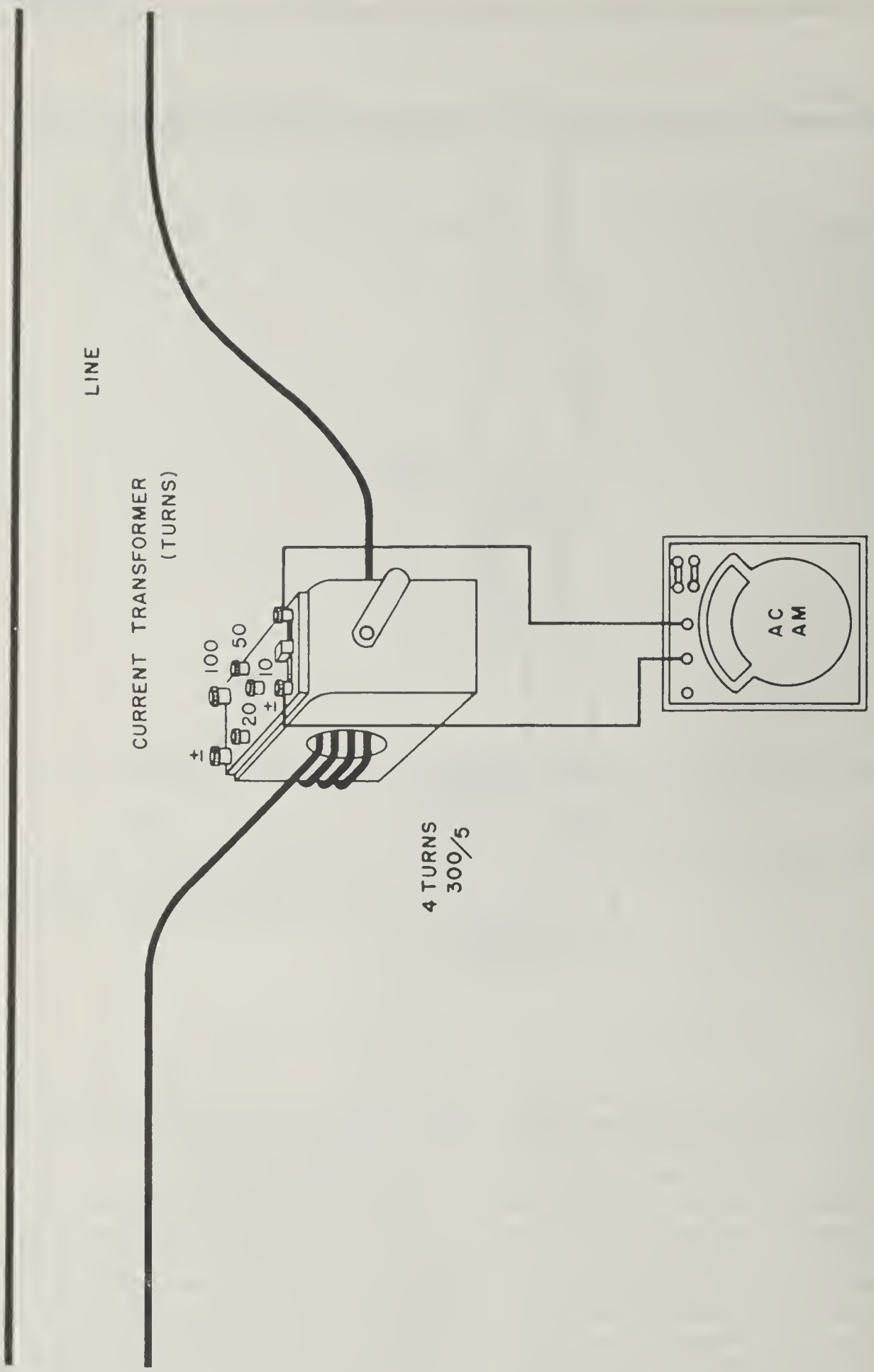



*Figure 205.1-X. Ac ammeter with current transformer using wrapped turns.*

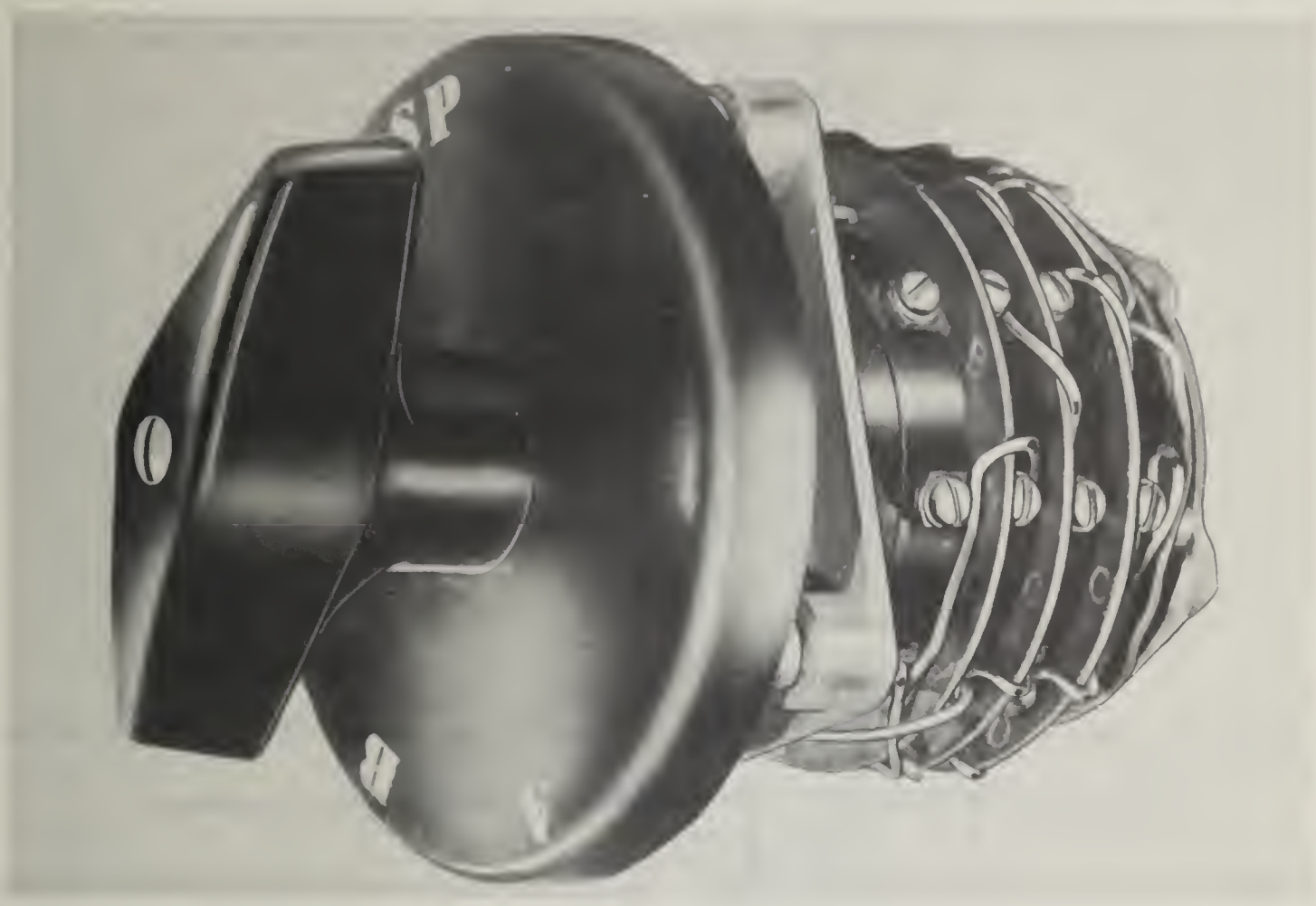


*Figure 205.1–XI. Ammeter transfer switch.*

shunt). For that reason, the shunts, the leads, and the instrument are calibrated as a unit and must be used together. Several different range shunts may be provided for each ammeter. Multiple shunts may be arranged in a single case, as shown in figure 102.1–III.

## 205.1.6 Wattmeters

*205.1.6.1. General*

Most wattmeters are electrodynamometer-type instruments. The fixed coils are the current coils and are placed in series with the load. The moving coils are connected across the source, or load. When the potential circuit is connected across the load side of the meter, the instrument indication will include the power used by the moving coil. When the potential circuit is connected across the source side of the meter, the instrument reading includes the power taken by the fixed coils. Under the conditions encountered in testing all but the very smallest type of generator sets, the instrument losses are so small (in the order of two watts) that they can be disregarded and, therefore, the position of the potential circuit is relatively unimportant. However, some wattmeters have a compensating circuit incorporated in their mechanisms which corrects for the moving coil losses. For those instruments which have compensating coils, the potential circuit always must be connected on the load side of the instrument as shown in figure 205.1–XV.

Wattmeters nominally are constructed for use on either high or low power factor circuits. The current coils of most high-power-factor instru-

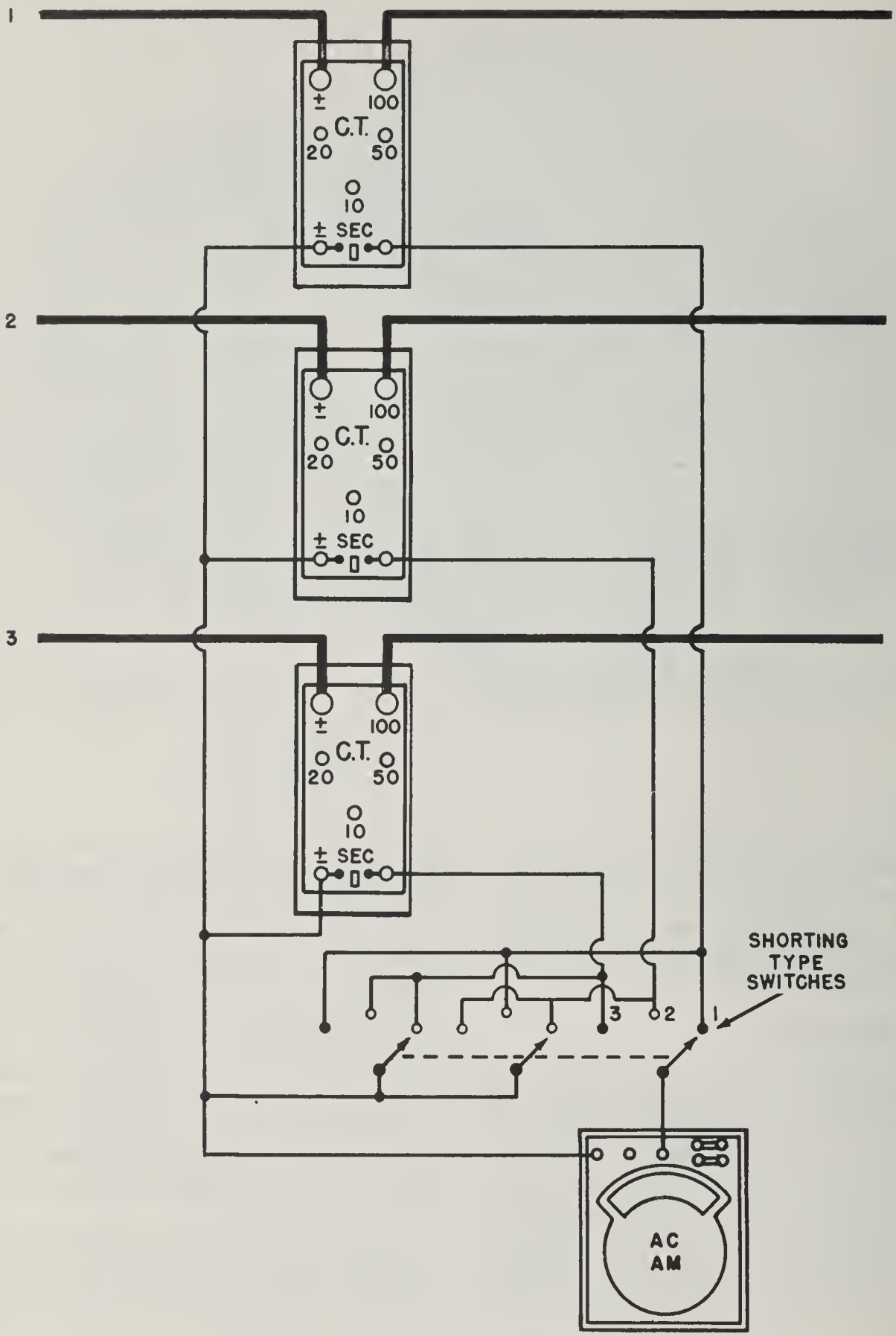



*Figure 205.1–XII. Ac ammeter with current transformers and selector switch.*

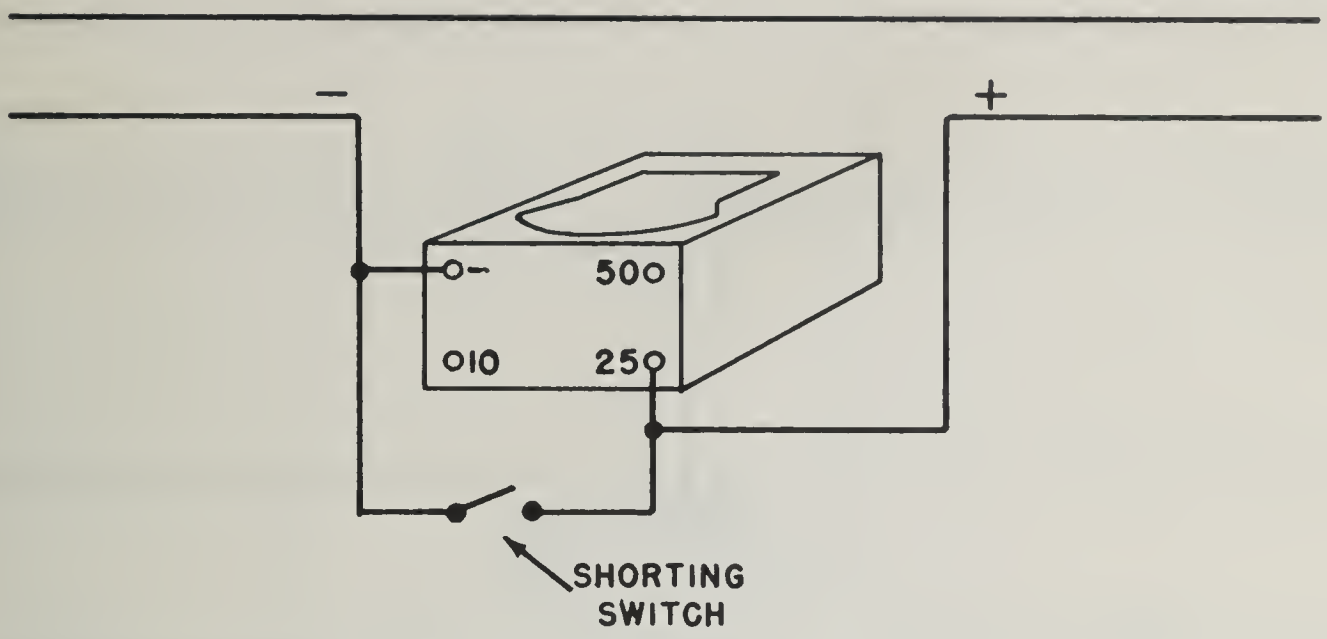



*Figure 205.1–XIII. Self-contained dc ammeter.*

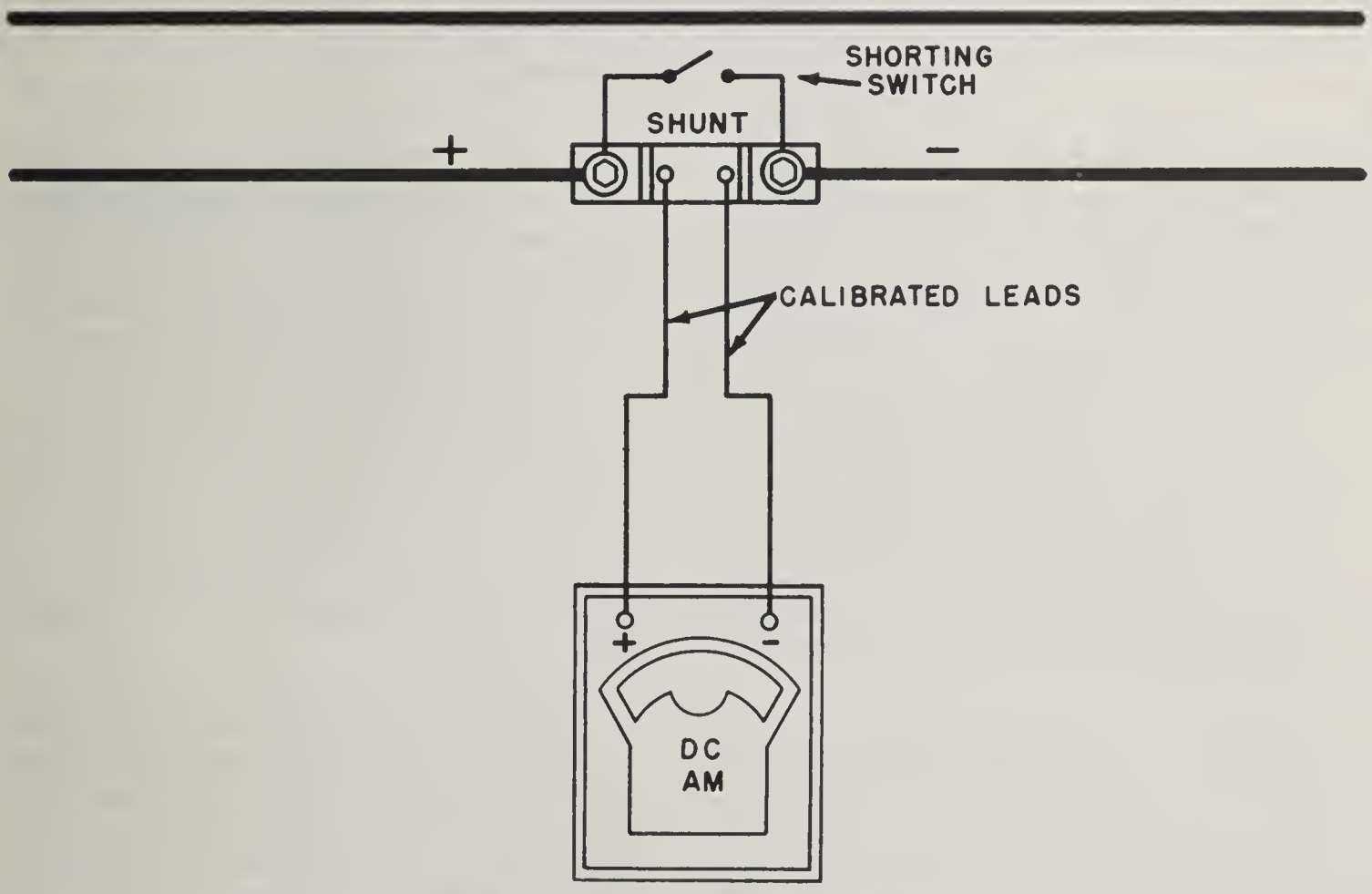



*Figure 205.1–XIV. Dc ammeter with shunt.*

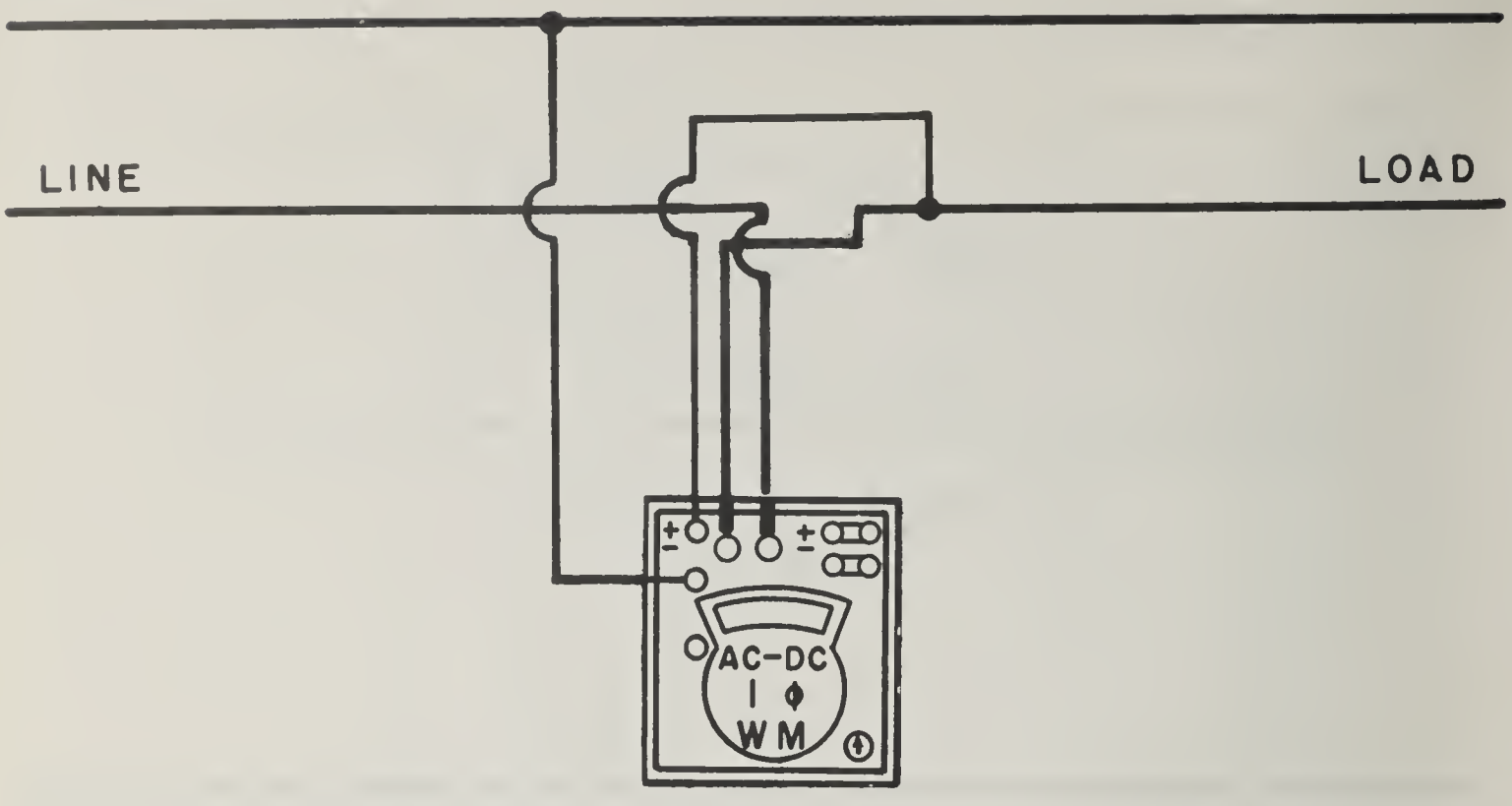



*Figure 205.1–XV. Single-phase wattmeter.*

ments can withstand a continuous overload of twice the nominal rated current, and have an average overload capacity in the potential circuit of one-and-one-half the nominal rated voltage. The maximum capacity in volt-amperes of most low-power-factor wattmeters is five times the maximum scale reading in watts.

The frequency range of most standard wattmeters is limited to the frequencies from 0 to 125 cycles per second. However, special instruments are made which indicate correctly up to 1,000 cycles per second. These high-range instruments are seldom compensated for temperature changes, however, the manufacturer's instructions must be carefully followed to correct readings at other than ordinary temperatures.

The range of wattmeters may be extended through the use of potential transformers (fig. 205.1–XVI), current transformers (fig. 205.1–XVII), or both (fig. 205.1–XVIII). The plus-or-minus binding post of the potential circuit must always be connected to the same side of the circuit under test which contains the current coil of the wattmeter. This is done so as to have the current and potential coils at the same potential to eliminate the electrostatic attraction between them, which otherwise would introduce an error in the indication. When current or potential transformers are used, it is necessary to connect the plus-and-minus binding post of the potential circuit to the plus-or-minus binding post of the current circuit. When both potential and current transformers are used, the connection between the plus-or-minus binding posts should be grounded. When instrument transformers are used on circuits exceeding 750 volts one terminal of the transformer secondaries must be grounded throught a wire equivalent in current carrying capacity to # 12 awg copper or larger. See Rules 93.B.3, 97.A.3, and 150.C of National Bureau of Standards Handbook H–30.

*205.1.6.2 Measurement of Polyphase Wattages*

A single-element wattmeter may be used to measure the power of a balanced, three-wire, polyphase system. This can be accomplished by means of a three-resistor network connected to form an artificial wye with the patential circuit of the instrument as one section of the network. The other two sections each have the same resistance as the instrument, and the voltage across the instrument then is equal to the phase voltage (or the voltage to the artificial neutral). The current circuit of the

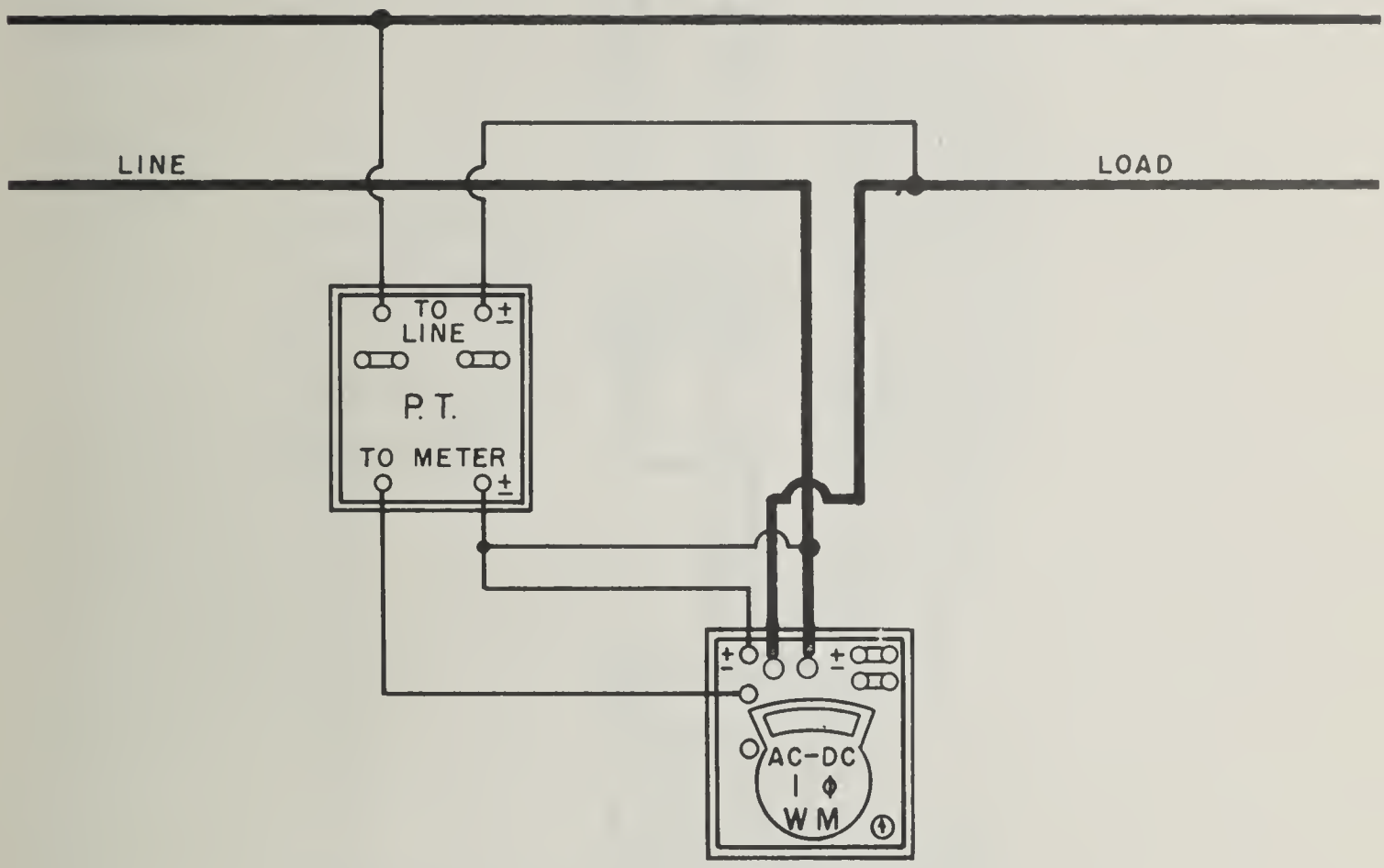



*Figure 205.1–XVI. Single-phase wattmeter with potential transformer.*

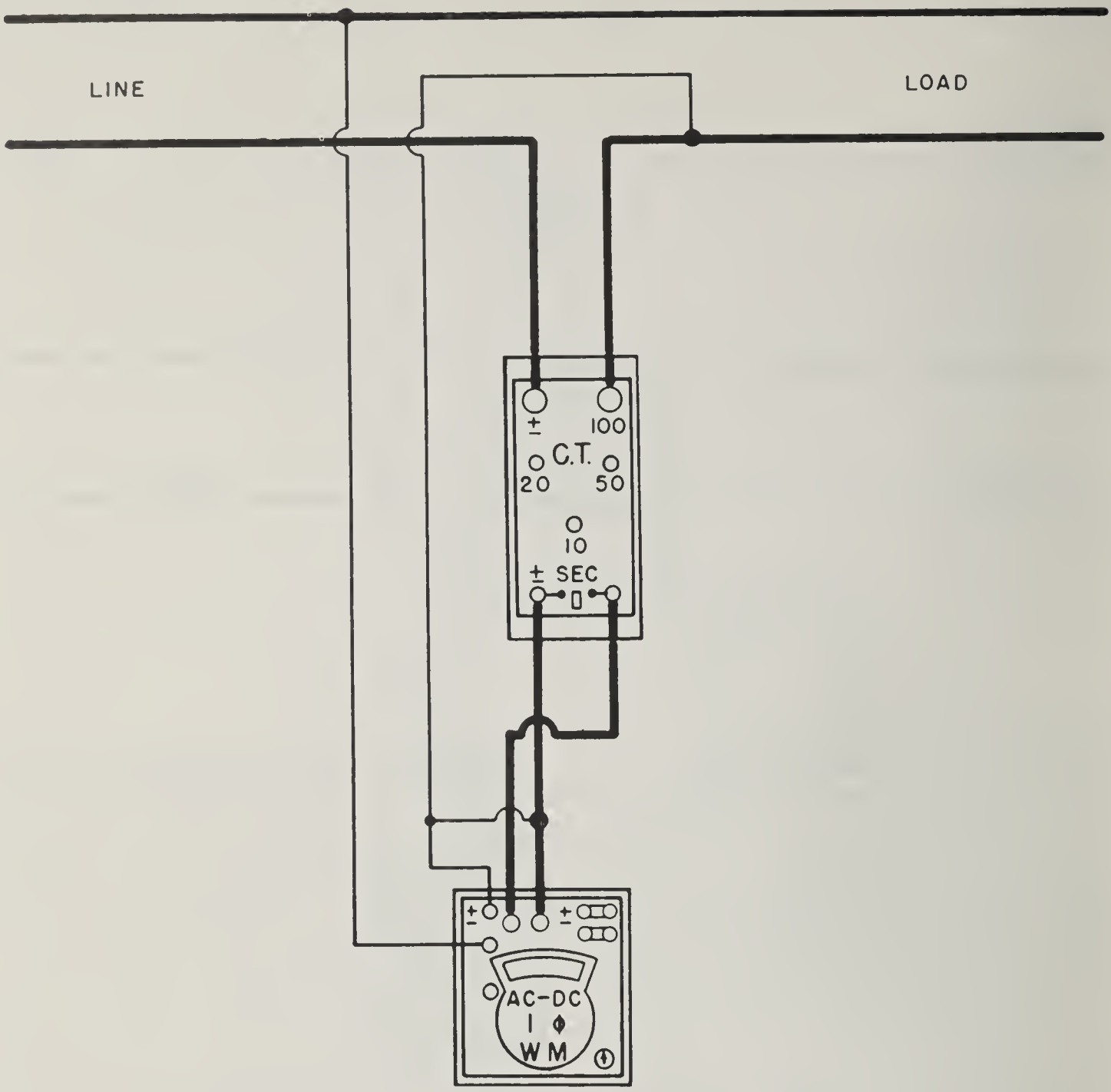



*Figure 205.1–XVII. Single-phase wattmeter with current transformer.*

instrument is connected in the same line as the potential circuit and the instrument indicates the power of one phase. The actual wattage will, therefore, be three times the meter reading. The connections for such use of a single-phase wattmeter are shown in figure 205.1–XIX.

It is also possible to measure the power in a balanced three-phase, three-wire system by connecting a single-element instrument as shown in figure 205.1–XX. It should be noted that the wattmeter current coils should be connected up for two times the current connection for one current transformer. Thus, if five-ampere transformer secondaries are used, the current coils of the wattmeter should be connected for 10 amperes. If the wattmeter reading (adjusted for the 10-ampere connection) is multiplied by the transformer ratio, the result will be the polyphase wattage.

Where the unbalanced voltages or currents are encountered, it is necessary to use more than one

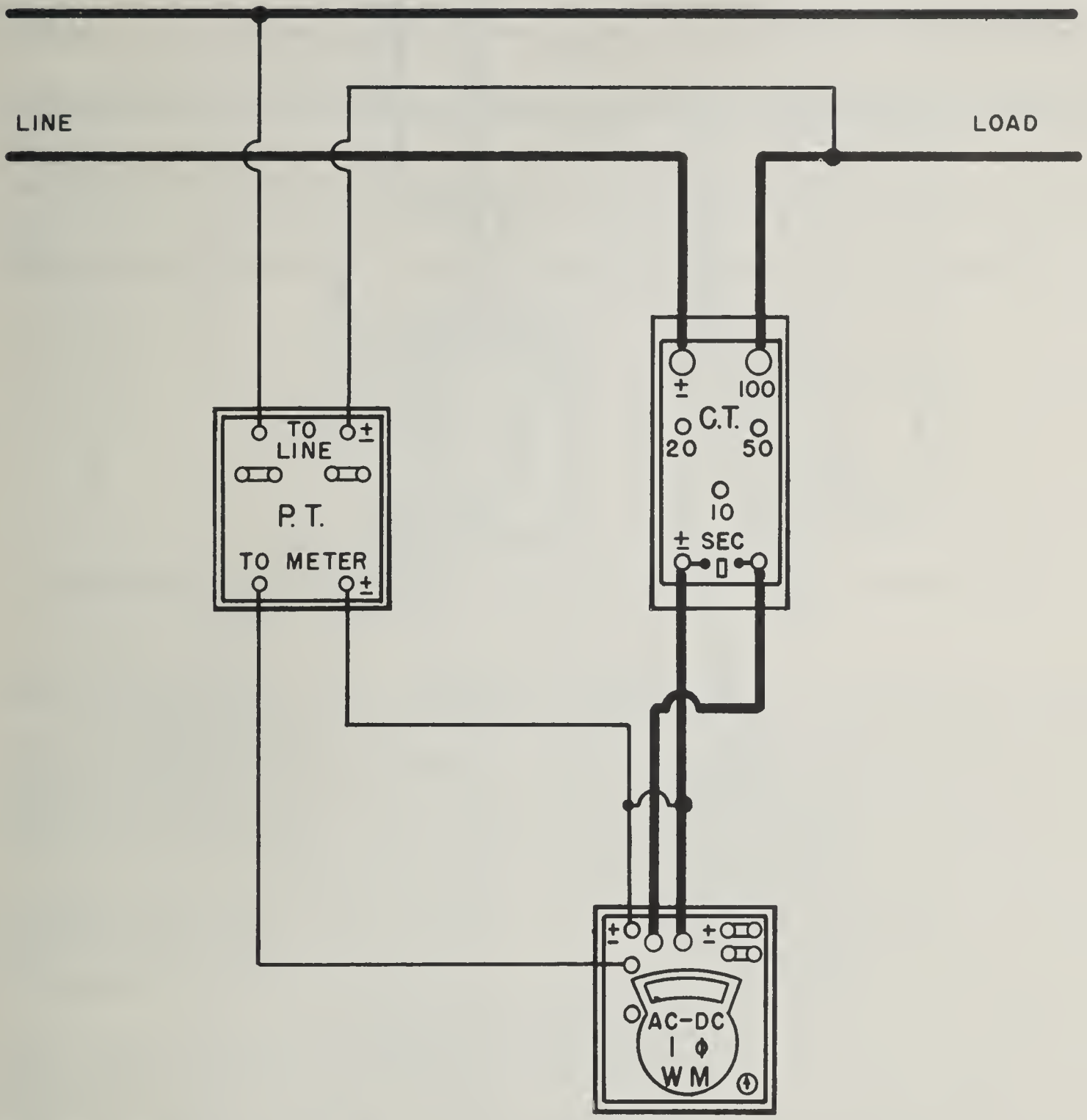



*Figure 205.1–XVIII. Single-phase wattmeter with potential and current transformers.*

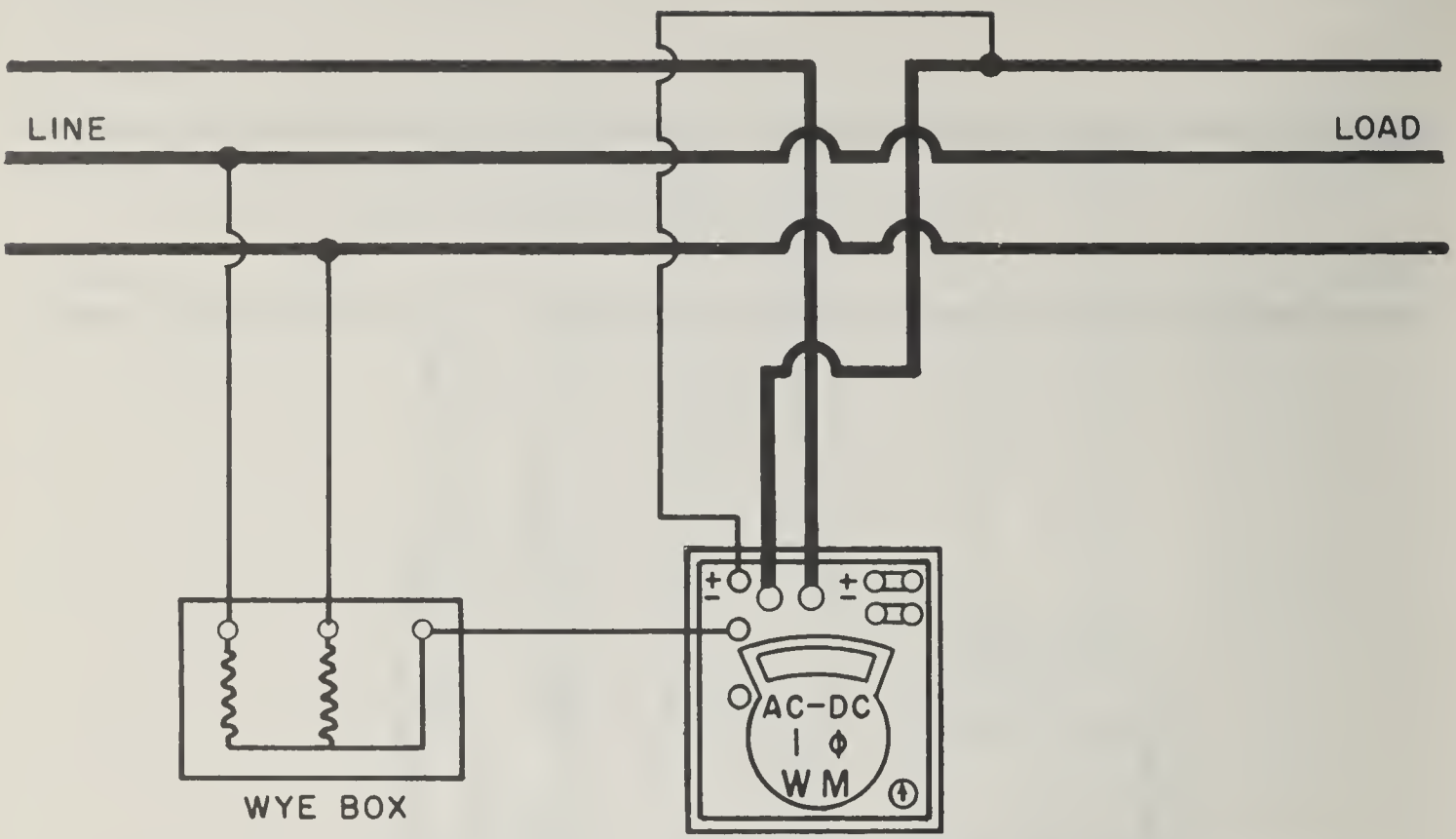



*Figure 205.1–XIX. Single-phase wattmeter with wye box on three-phase, three-wire balanced system.*

meter to measure the power in a polyphase system. These meters can be combined in one unit to form a direct reading polyphase wattmeter. However, Blondel's Theorem states that "true power can be measured by one less wattmeter element than the number of wires of the system, provided that one wire can be made common to all element potential circuits." Figure 205.1–XXI shows the connections for two single-phase wattmeters used on a three-phase, three-wire system. If both instruments deflect toward the top of the scale, when connected as shown, the power is the sum of their indications. If one instrument deflects negatively, which will be the case when the power factor is below 50 percent, the reversing switch of that wattmeter should be changed and the power will be the reading of the first instrument minus the reading of the reversed instrument.

The connections for a two-element polyphase wattmeter, used on a three-phase, three-wire system, are shown in figure 205.1–XXII. Figure 205.1–XXIII shows the use of the same instrument on a *balanced* four-wire, three-phase system. This instrument *will not read correctly* on an unbalanced four-wire, three-phase system.

Figures 205.1–XXIV, 205.1–XXV, and 205.1–XXVI show the use of a two-element, polyphase wattmeter on a balanced four-wire, three-phase system, using potential transformers, current transformers, or both.

When the wattage of a four-wire, three-phase unbalanced system is required, three wattmeters connected as shown in figure 205.1–XXVII shall be used. The sum of the three readings is the required wattage.

In some instances it may be necessary to measure the wattage of a single-phase system with a polyphase wattmeter. Figures 205.1–XXVIII and 205.1–XXIX show wiring connections which will permit the use of such an instrument. In the hookup of figure 205.1–XXVIII, the wattmeter will read directly. In the hookup of figure 205.1–XXIX, the wattmeter reading must be multiplied by the ratios of both the current and potential transformers.

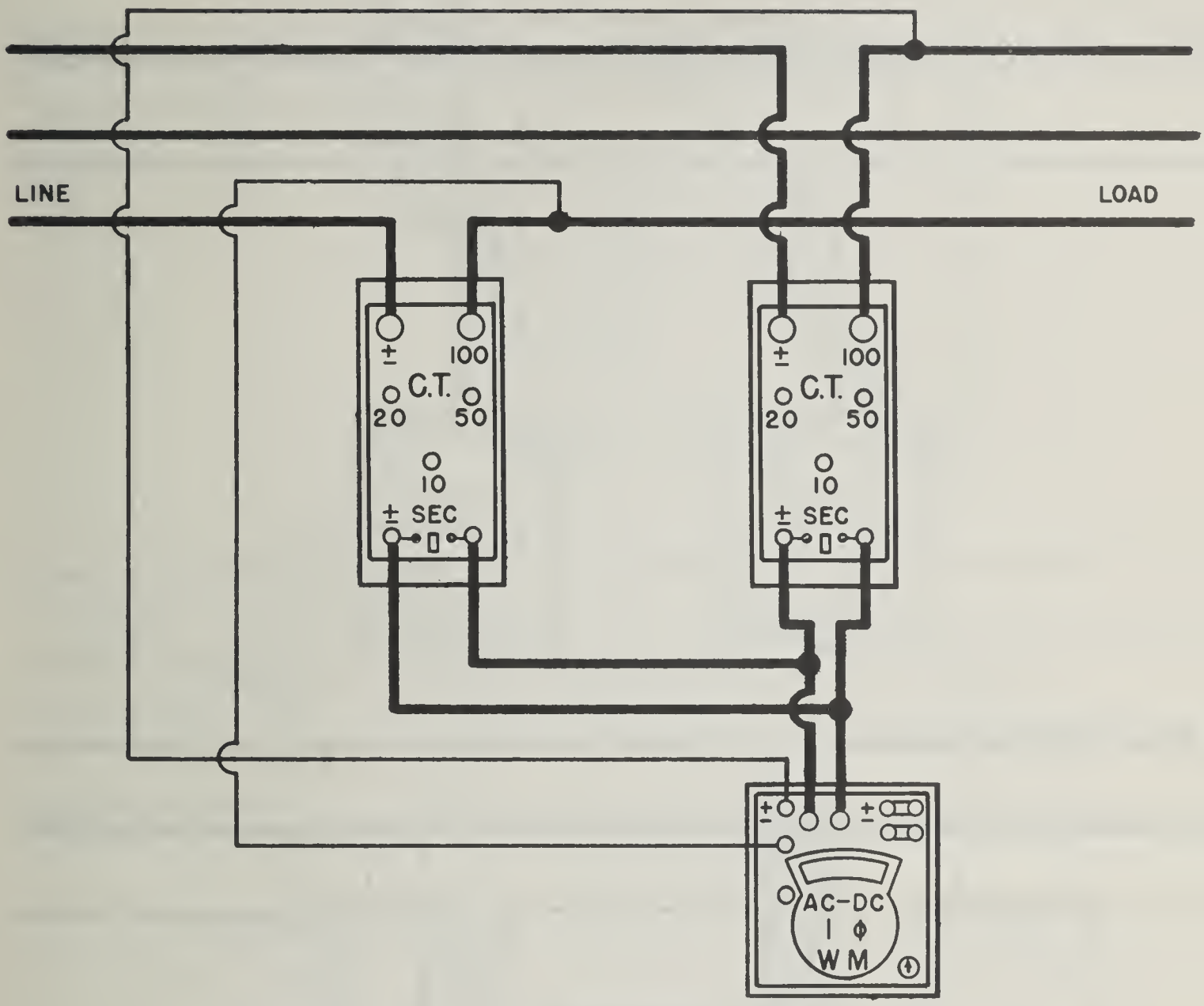



*Figure 205.1-XX. Singles-phase wattmeter on three-wire, three-phased balanced system using two current transformers.*

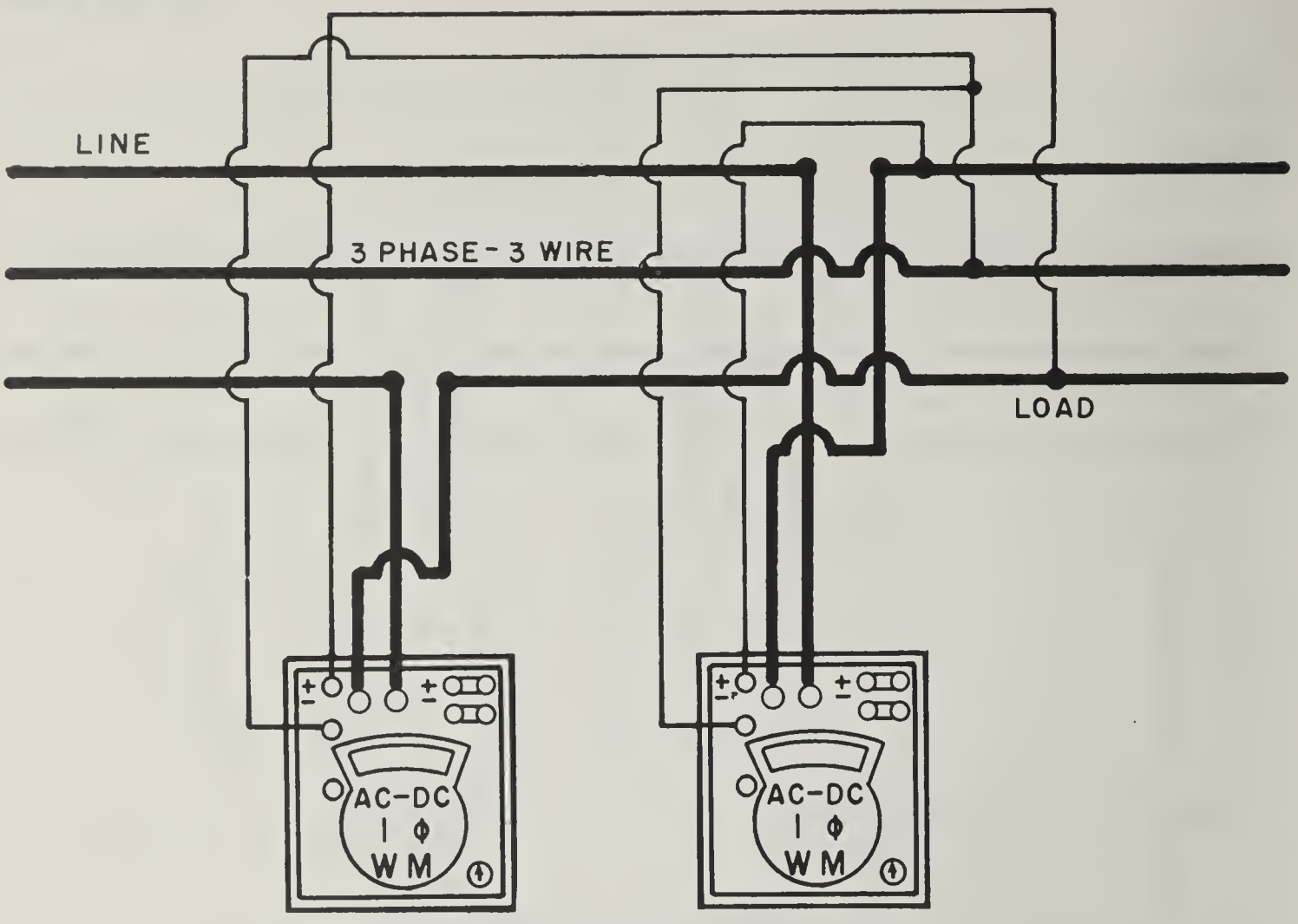



*Figure 205.1–XXI. Two sinble-phase wattmeters on three-phase, three-wire system.*

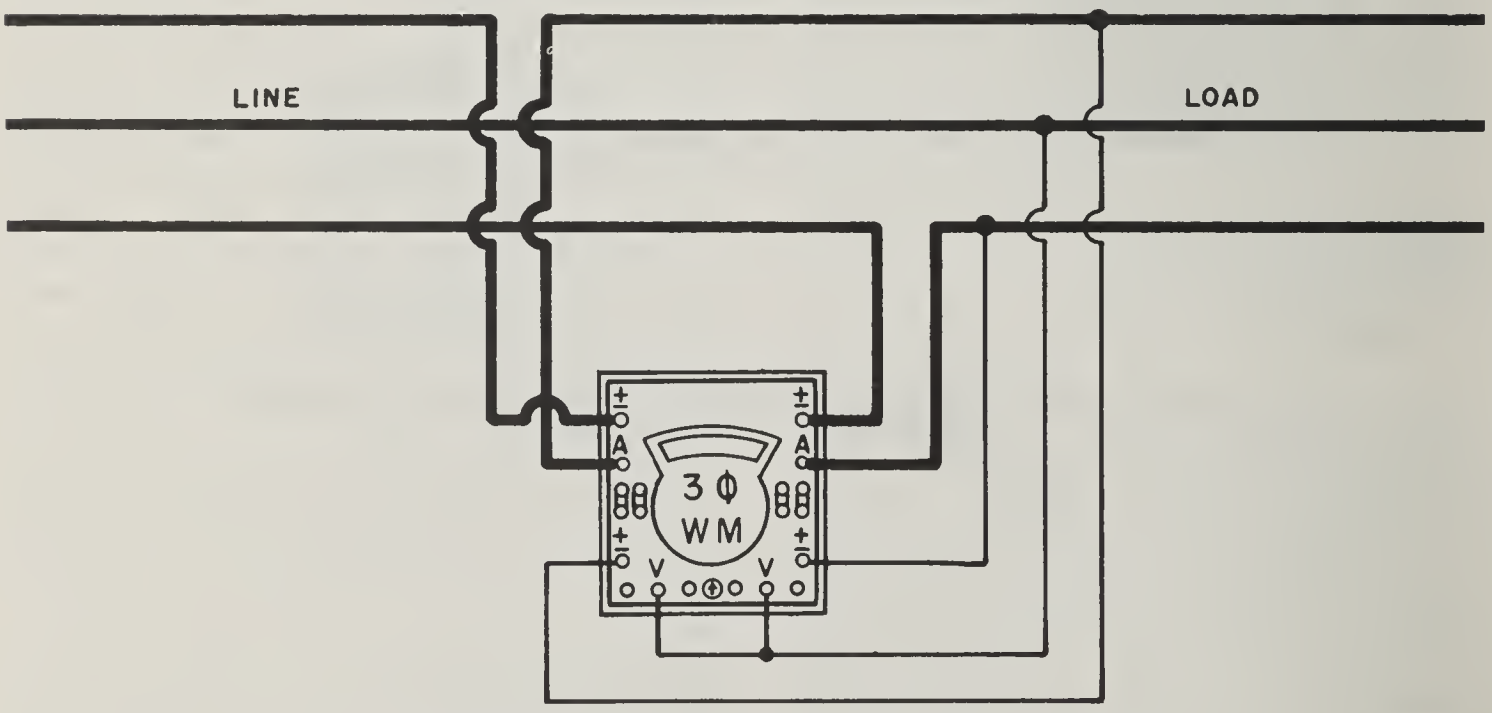



*Figure 205.1–XXII. Two-element, polyphase wattmeter on three-wire, three-phase system.*

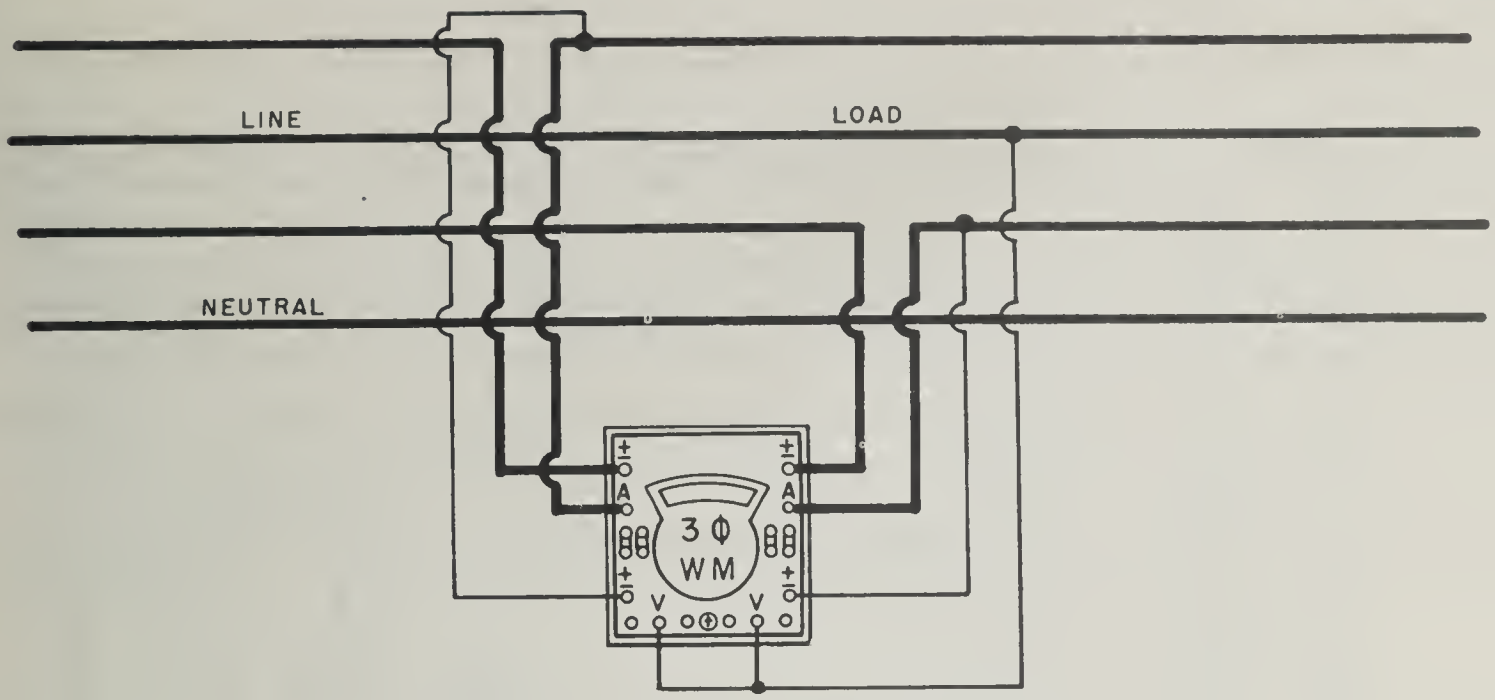



*Figure 250.1–XXIII. Two-element, polyphase wattmeter on balanced four-wire, three-phase system.*

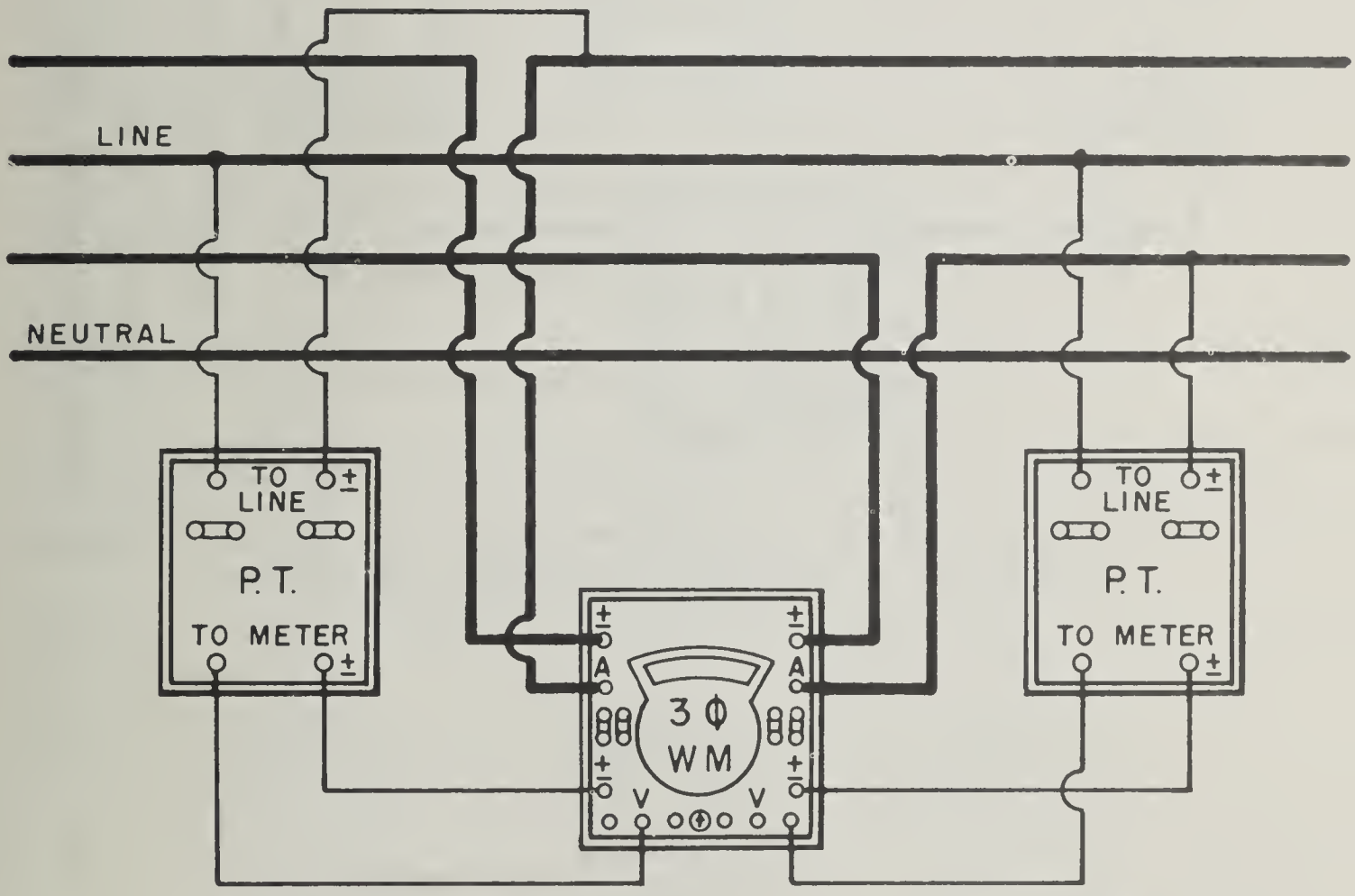



*Figure 205.1–XXIV. Two-element, polyphase wattmeter with potential transformer on balanced four-wire, three-phase system.*



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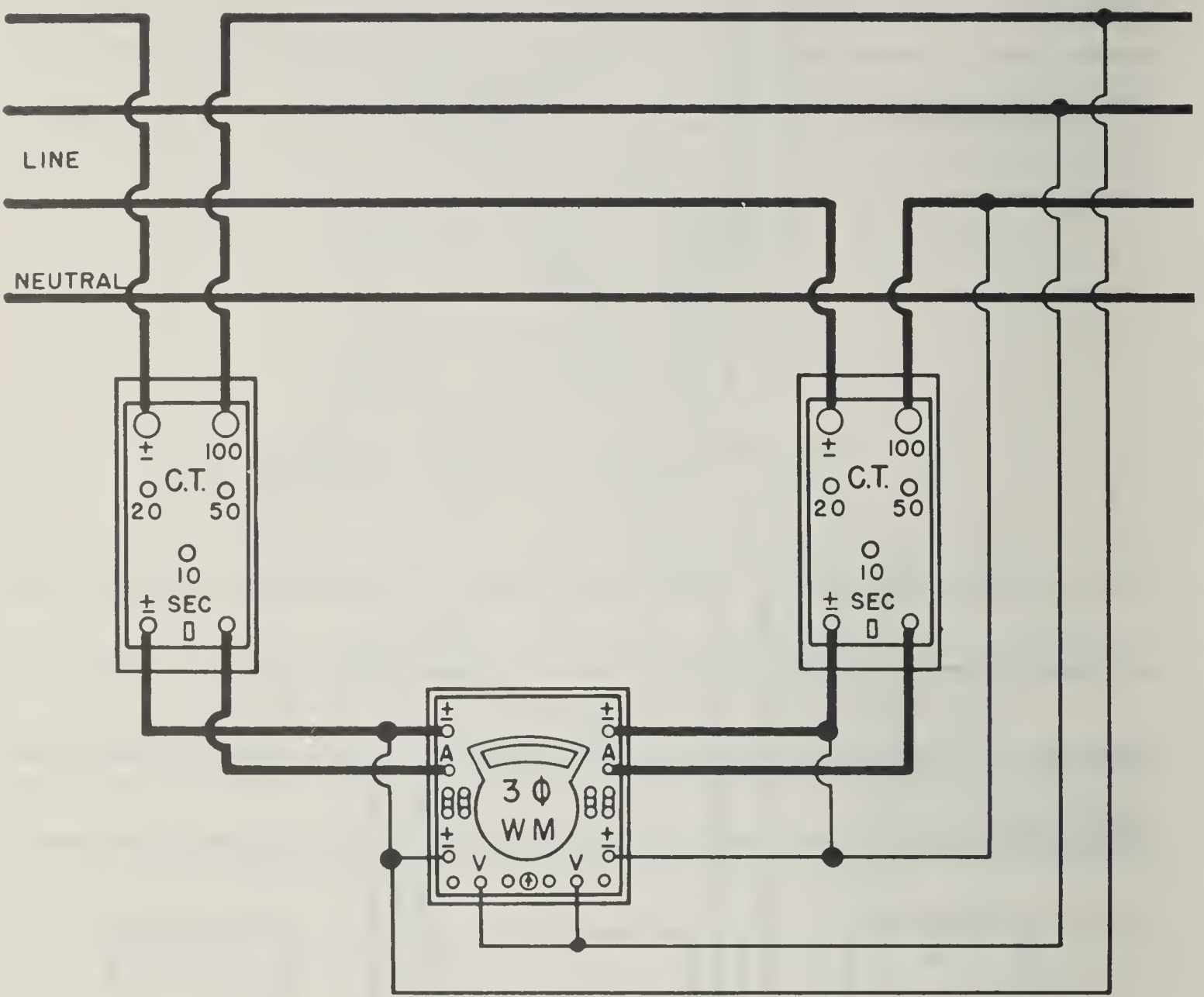



*Figure 205.1–XXV. Two-element, polyphase wattmeter with current transformer on balanced four-wire, three-phase system.*

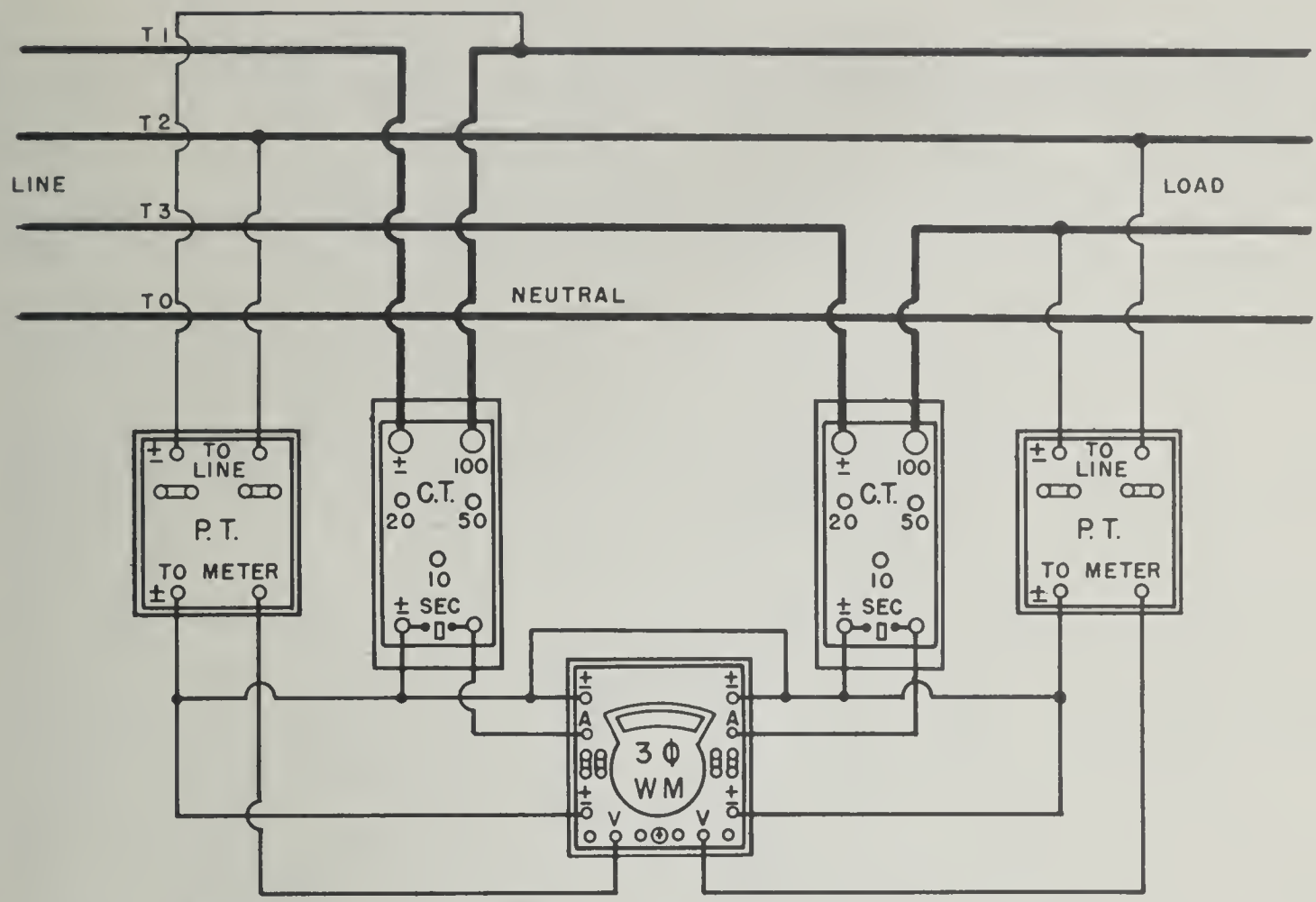



*Figure 205.1–XXVI. Two-element, polyphase wattmeter with both current and potential transformers on balanced four-wire, three-phase system.*

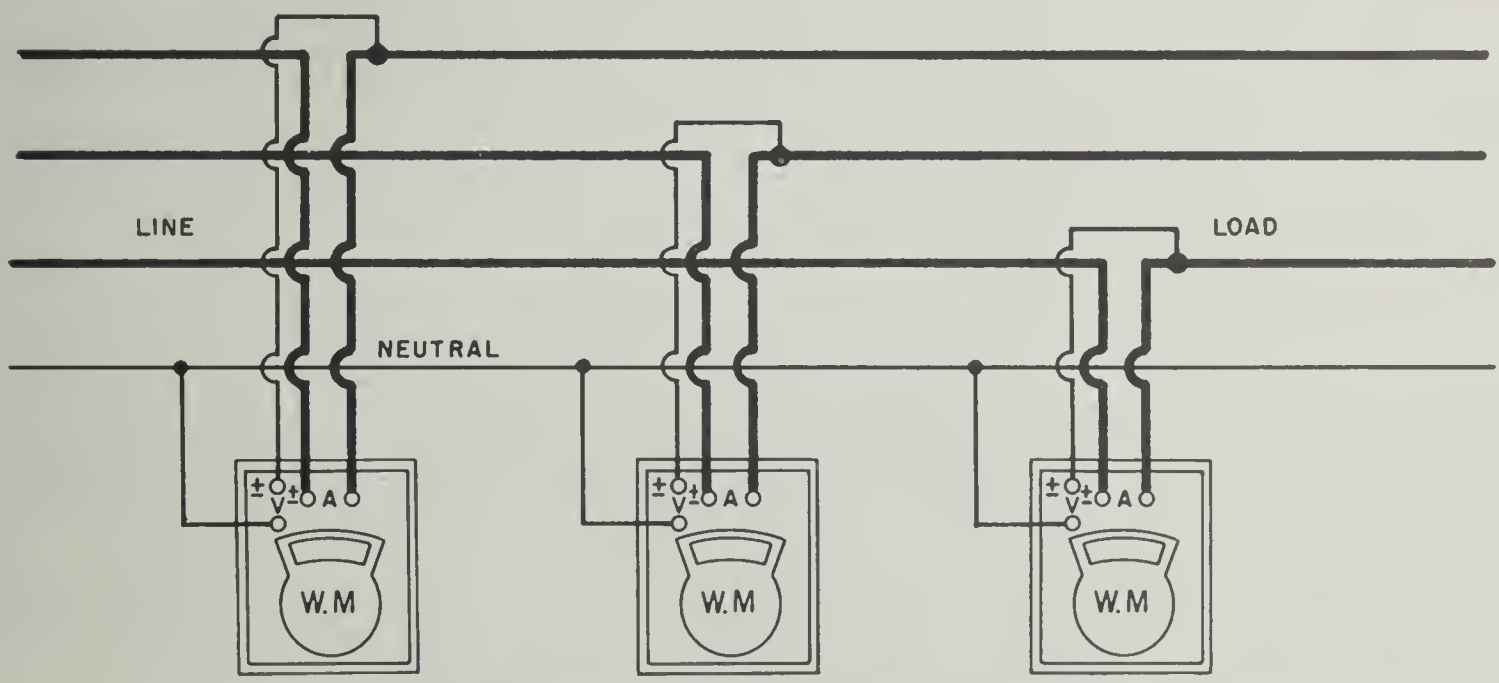



*Figure 205.1–XXVII. Three wattmeters used on unbalanced four-wire, three-phase system.*

### 205.1.7 Power Factor

The power factor of a single-phase circuit can be determined by using a single-phase wattmeter, as shown in figure 205.1–XV, and a voltmeter and ammeter, as shown in figures 205.1–I and 205.1–VIII. Since the wattmeter reads $EI \cos \theta$ (volts $X$ amperes $X$ power factor), if the wattmeter reading is divided by the product of the voltmeter reading times the ammeter reading, the result will be the power factor ($\cos \theta$).

$$\frac{\text{Watts}}{\text{Volts } X \text{ Amps}} = \text{Power Factor}$$

This value may be read directly by using a single-phase power factor meter hooked up as shown in figure 205.1–XXX. Figure 205.1–XXXI shows the same instrument used with a potential transformer and a current transformer.

When the power factor of a balanced three-phase system is desired, it may be computed by using a polyphase wattmeter, as shown in figure 205.1–XXII, and a voltmeter and ammeter, as shown in figures 205.1–I and 205.1–VIII. Since the wattmeter reads 1.732 $E_{line}$ $I_{phase}$ $\cos \theta$ (1.732 $X$ line-to-line volts $X$ phase current $X$ power factor), if the wattmeter reading is divided by the product of the voltmeter reading, the ammeter reading, and 1.732, the result will be the power factor ($\cos \theta$). This value may be obtained directly by the use of a polyphase power factor meter, as shown in figures 205.1–XXXII, 205.1–XXXIII, 205.1–XXXIV, and 205.1–XXXV, which illustrate the method of connection of the instrument when used alone, with potential transformers, with current transformer, and with both current and potential transformers. Care must be taken to see that the wiring of a polyphase power factor meter is correct, or the readings will be completely erroneous. A check always should be made against the computed value of the power factor, as given above, the first time the instrument is used in a circuit.

Since the system must be balanced (equal voltages, currents, and power factors on all three phases), to use a power factor meter, a single-phase instrument used as shown in figure 205.1–XXX, between one line and neutral, also may be used to indicate the system power factor.

The power factor of an unbalanced polyphase system is a complicated, controversial subject,

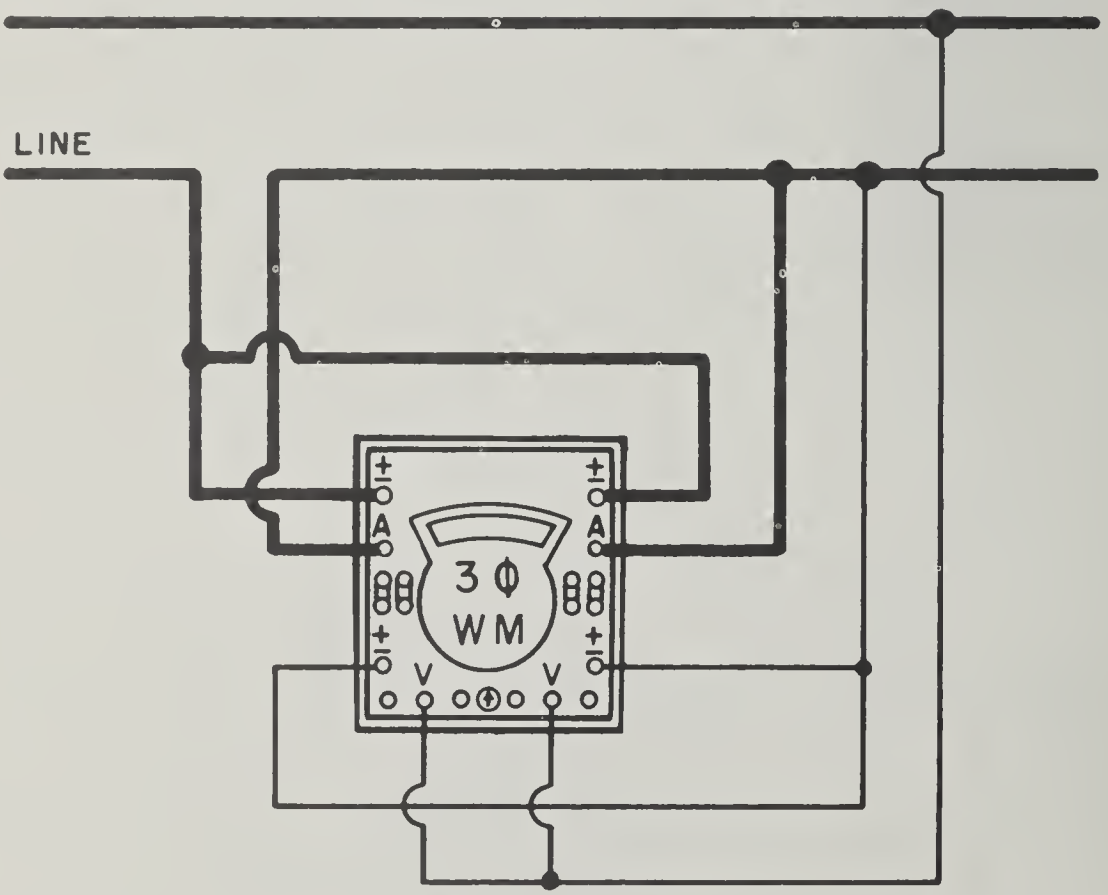



*Figure 205.1–XXVIII. Polyphase wattmeter used on single-phase system.*

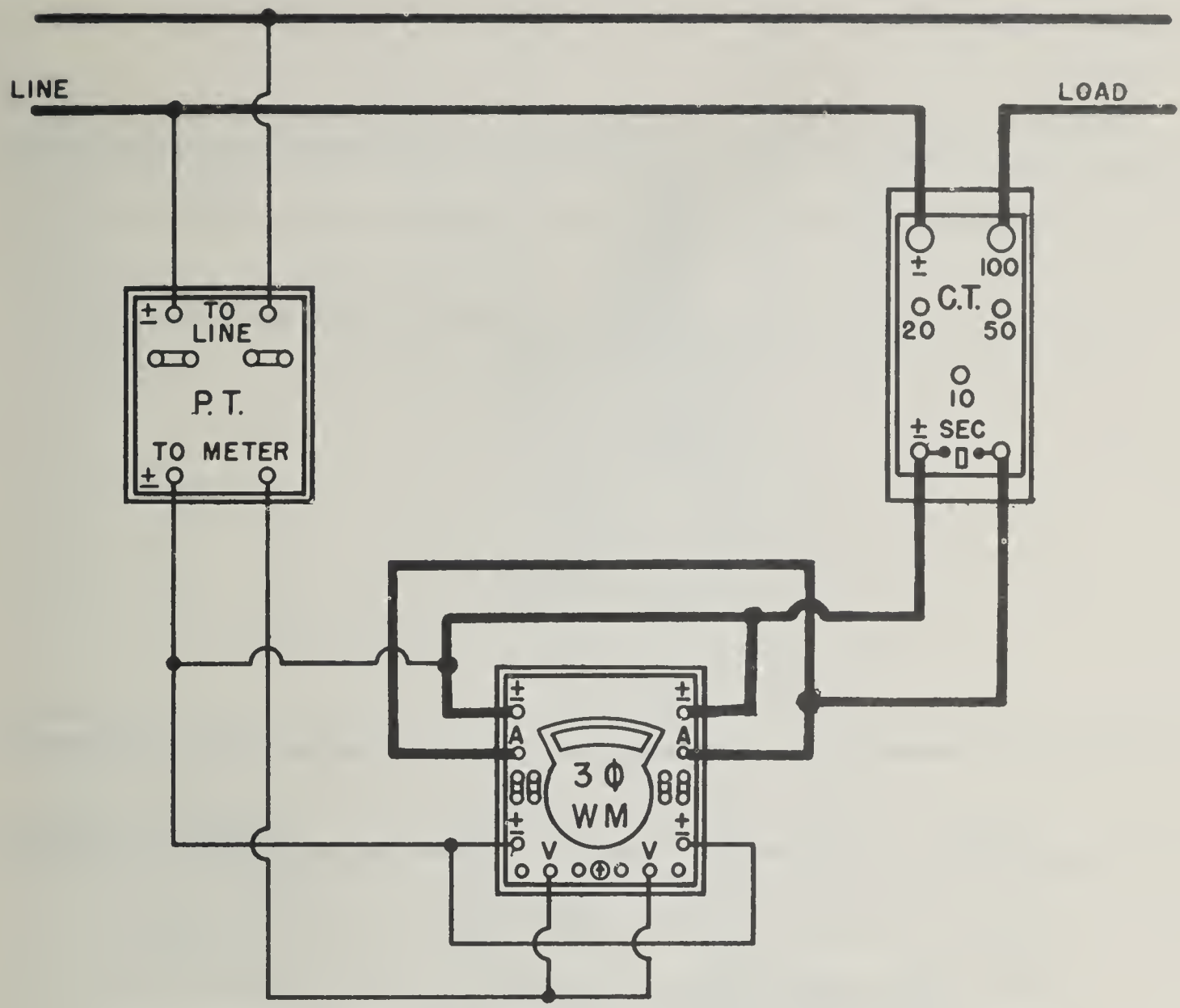



*Figure 205.1–XXIX. Polyphase wattmeter, with current and potential transformers, used as a single-phase instrument.*

beyond the scope of this handbook, and it is not required in any of the test methods.

### 205.1.8 Reactive Volt-Amperes

Occasionally it is necessary to determine the reactive volt-amperes of a polyphase system. This may be accomplished in a balanced three-phase, three-wire system by using a single-element wattmeter, as shown in figure 205.1–XXXVI. The scale reading must be multiplied by 1.732 to get the values of VAR's.

Figure 205.1–XXXVII shows the use of a polyphase wattmeter with a combined phase-shifting autotransformer. This may be used on a three-phase, three-wire system whose voltages are balanced but whose currents are not.

### 205.1.9 Frequency Meters

Frequency meters are connected in circuits in a manner similar to a voltmeter. Figures 205.1–XXXVIII and 205.1–XXXIX illustrate the connections for the use of such instruments.

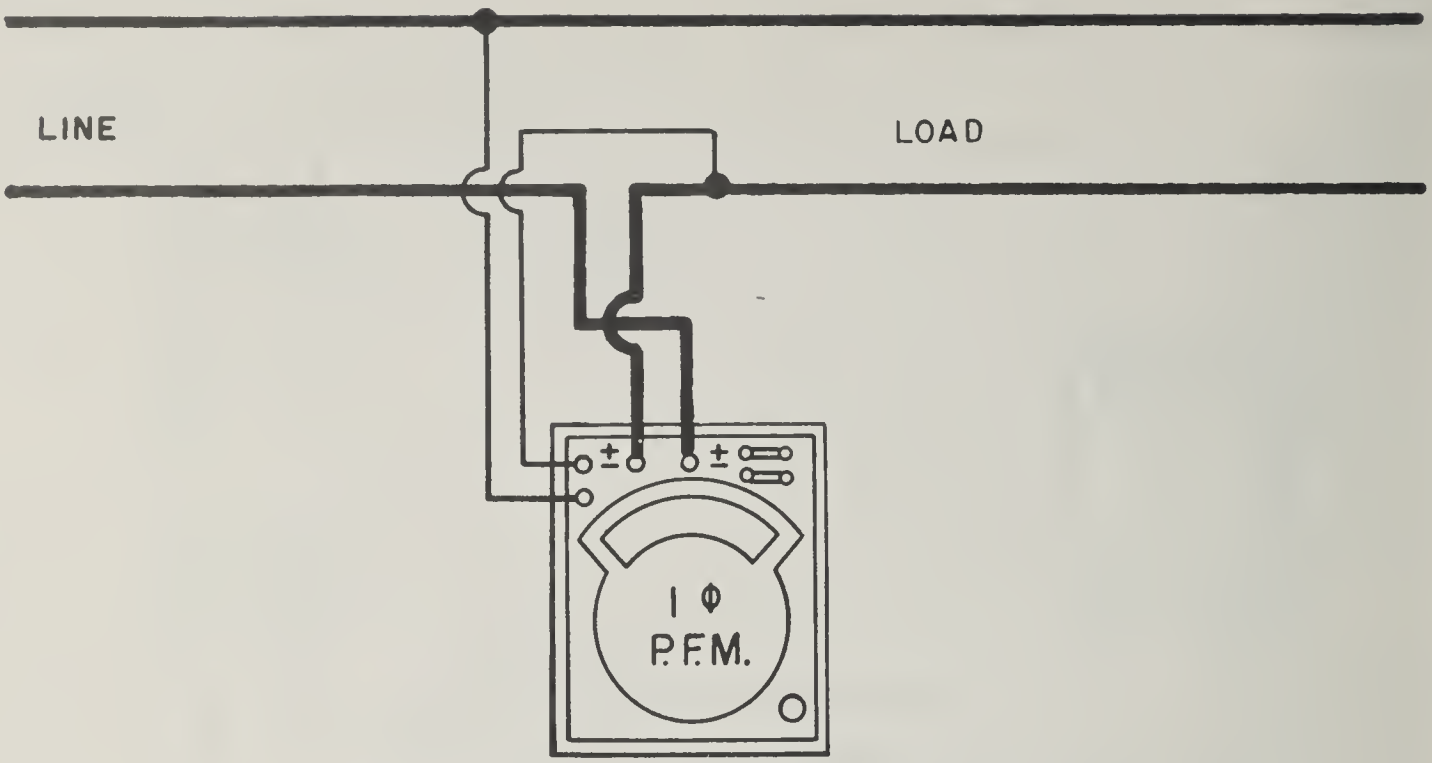



*Figure 205.1–XXX. Single-phase power factor meter.*

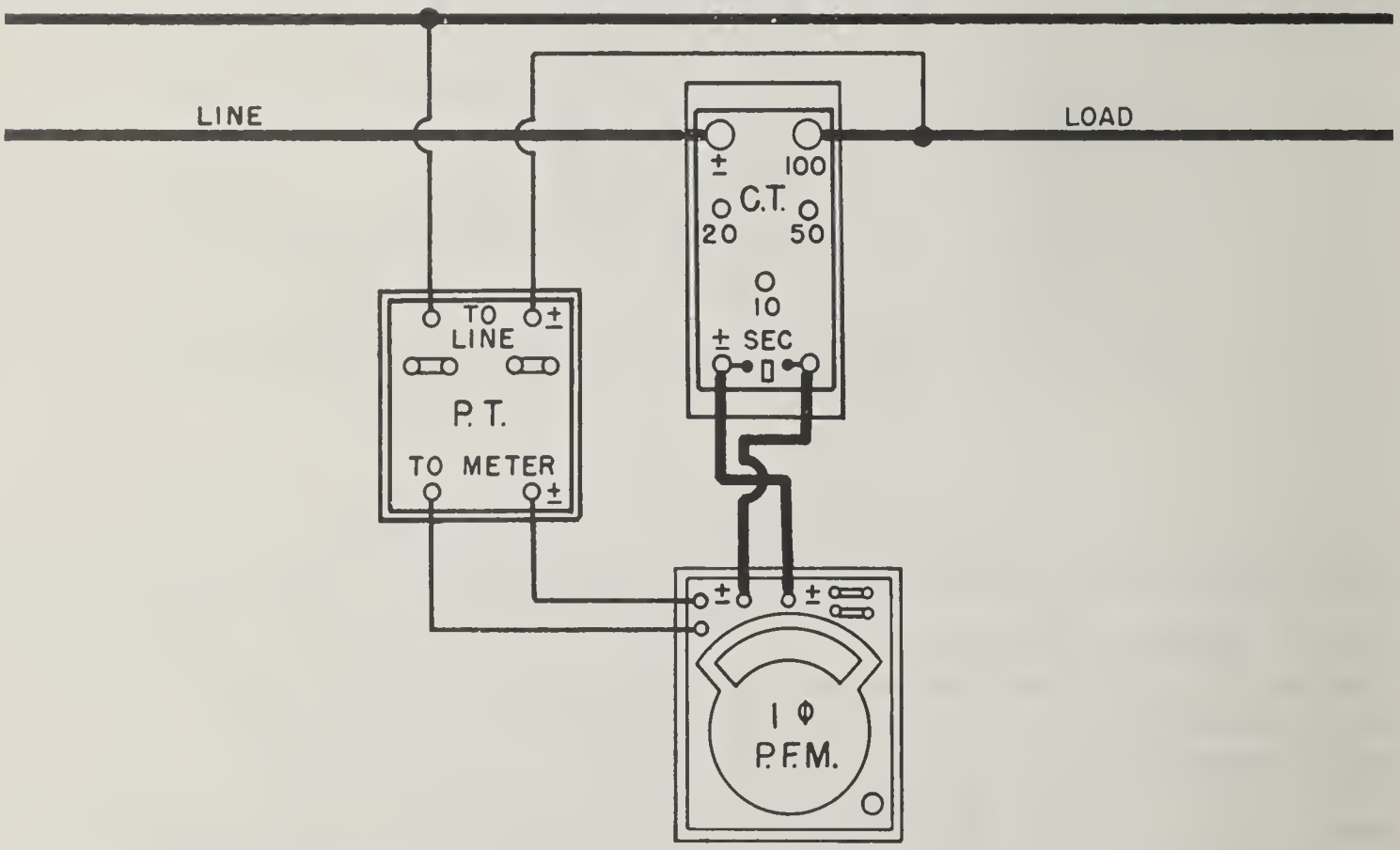



*Figure 205.1–XXXI. Single-phase power factor meter with potential and current transformers.*

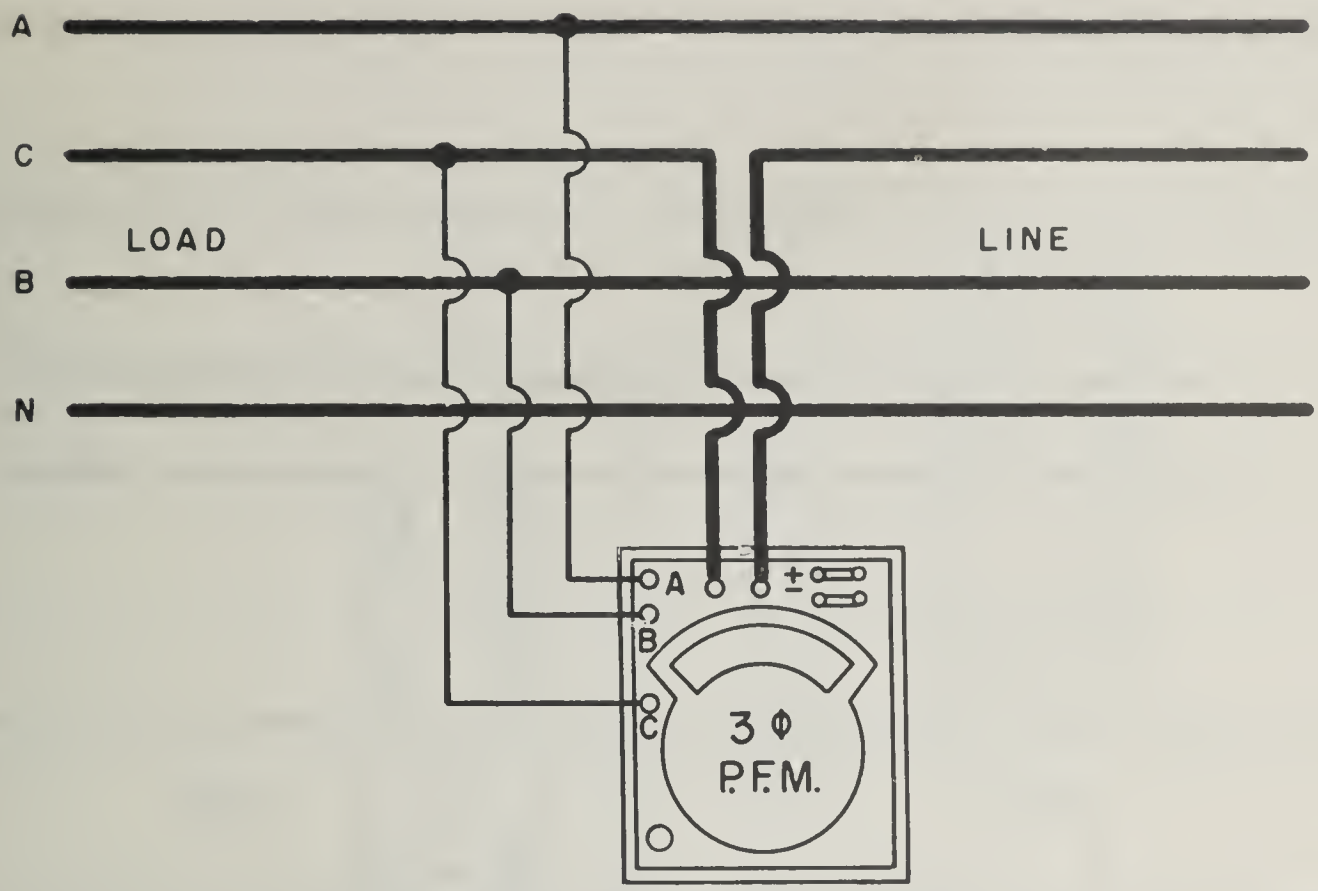



*Figure 205.1-XXXII. Three-phase power factor meter.*

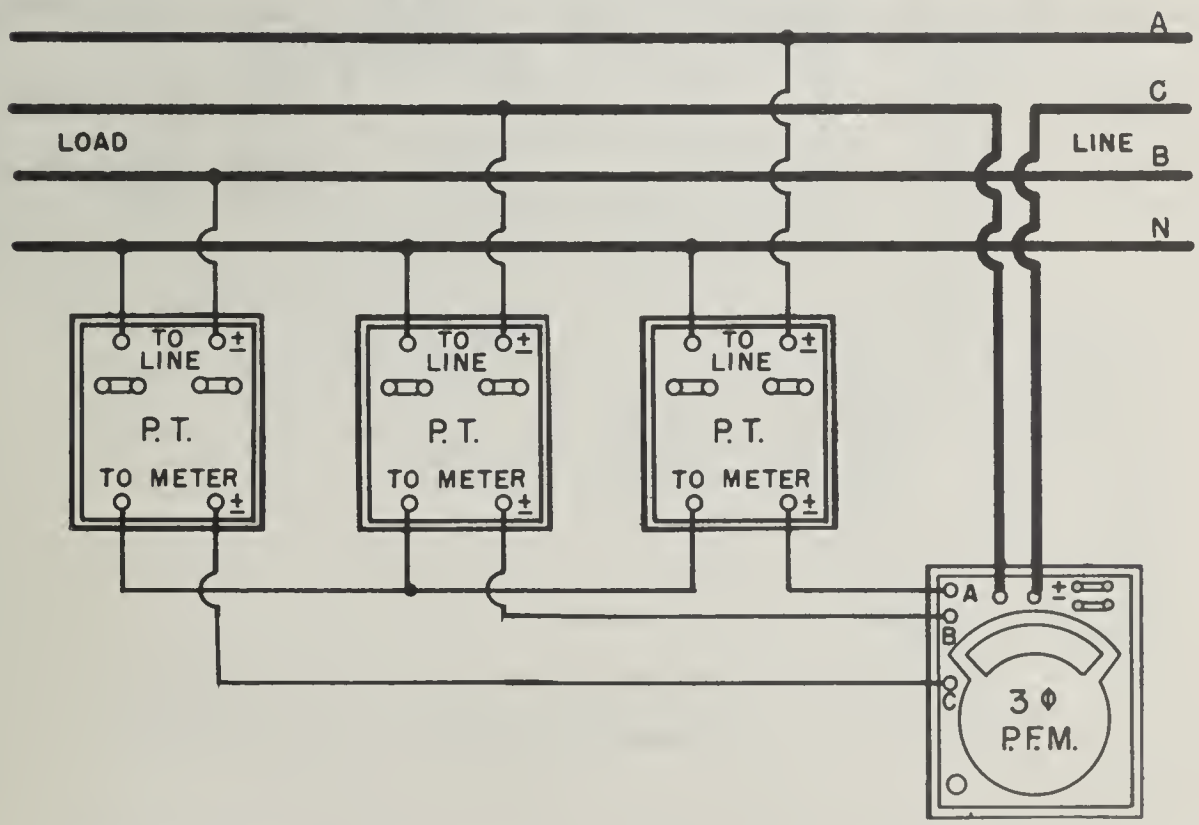



*Figure 205.1-XXXIII. Three-phase power factor meter with potential transformers.*

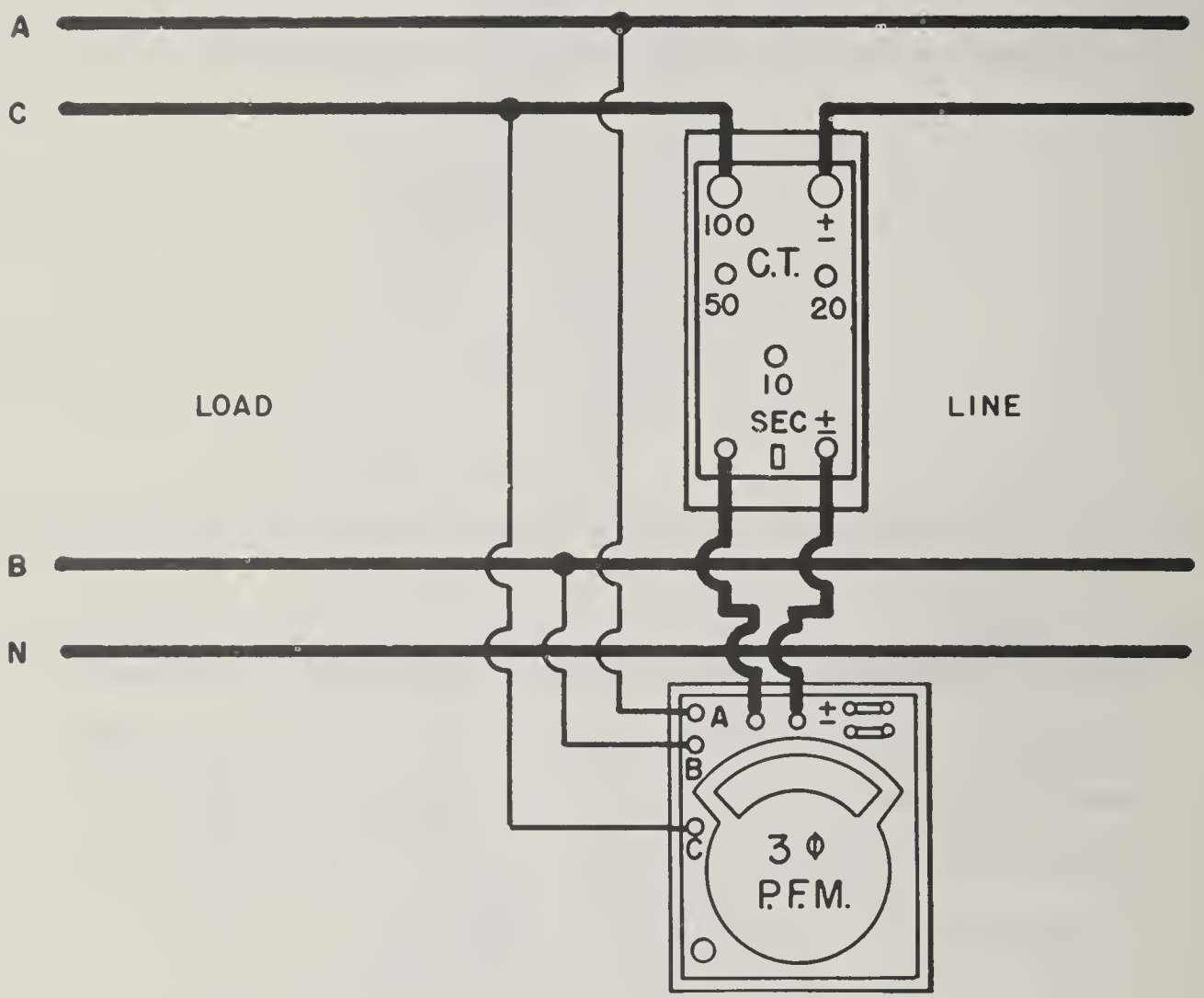



*Figure 205.1–XXXIV. Three-phase power factor meter with current transformer.*

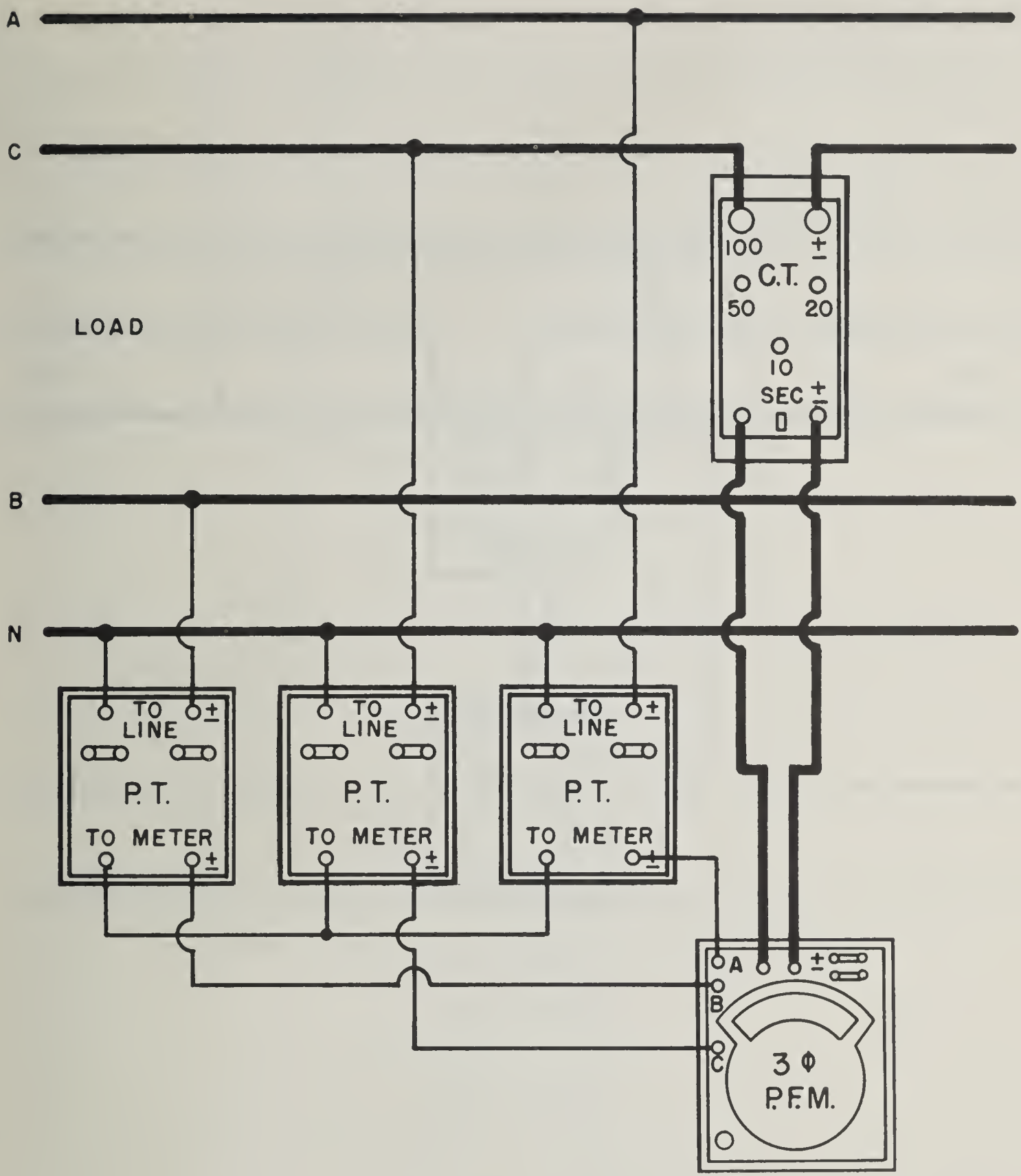



*Figure 205.1–XXXV. Three-phase power factor meter with both potential and current transformers.*

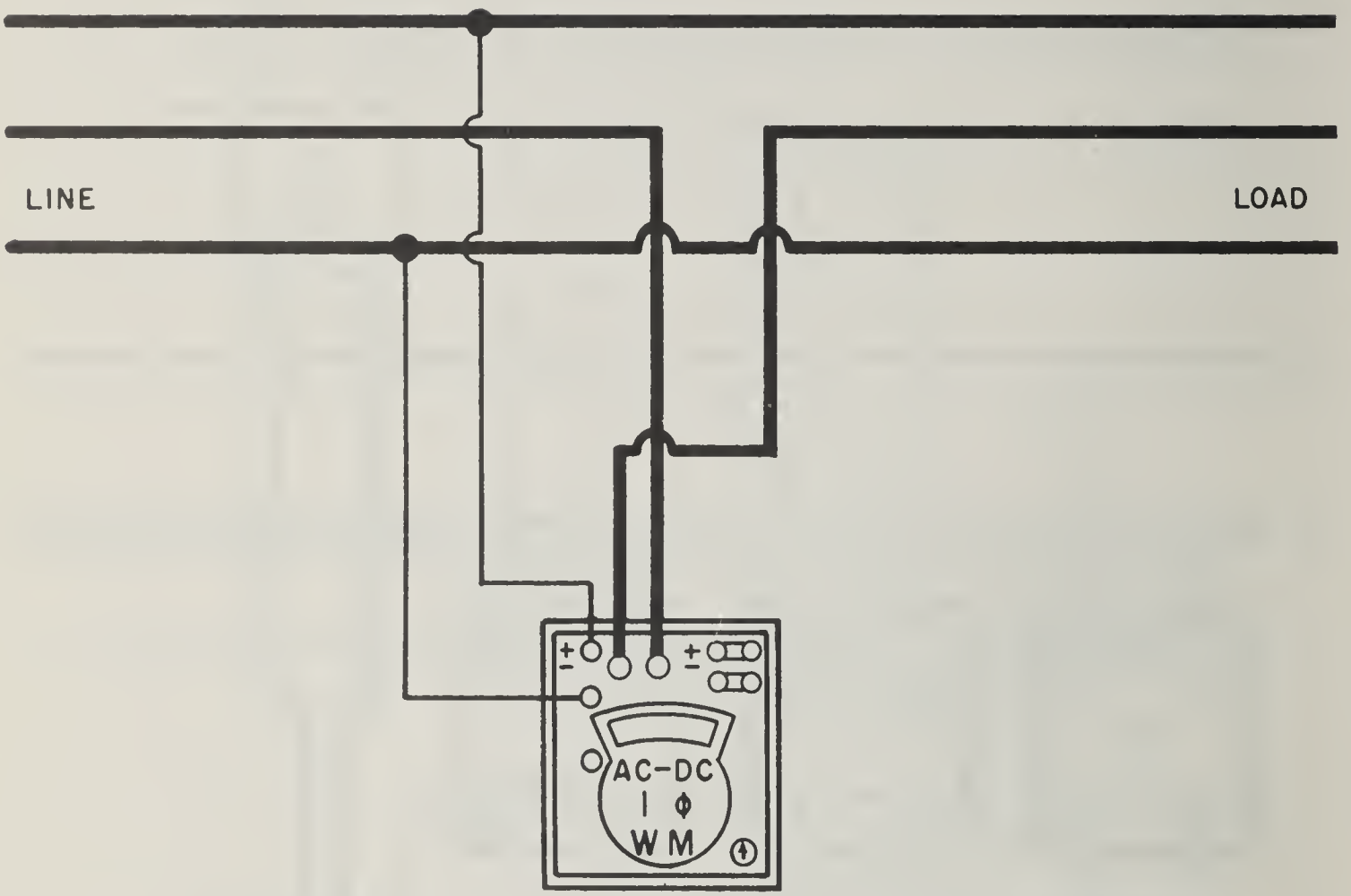



*Figure 205.1–XXXVI. Single-element wattmeter used as a varmeter on three-phase balanced circuit.*

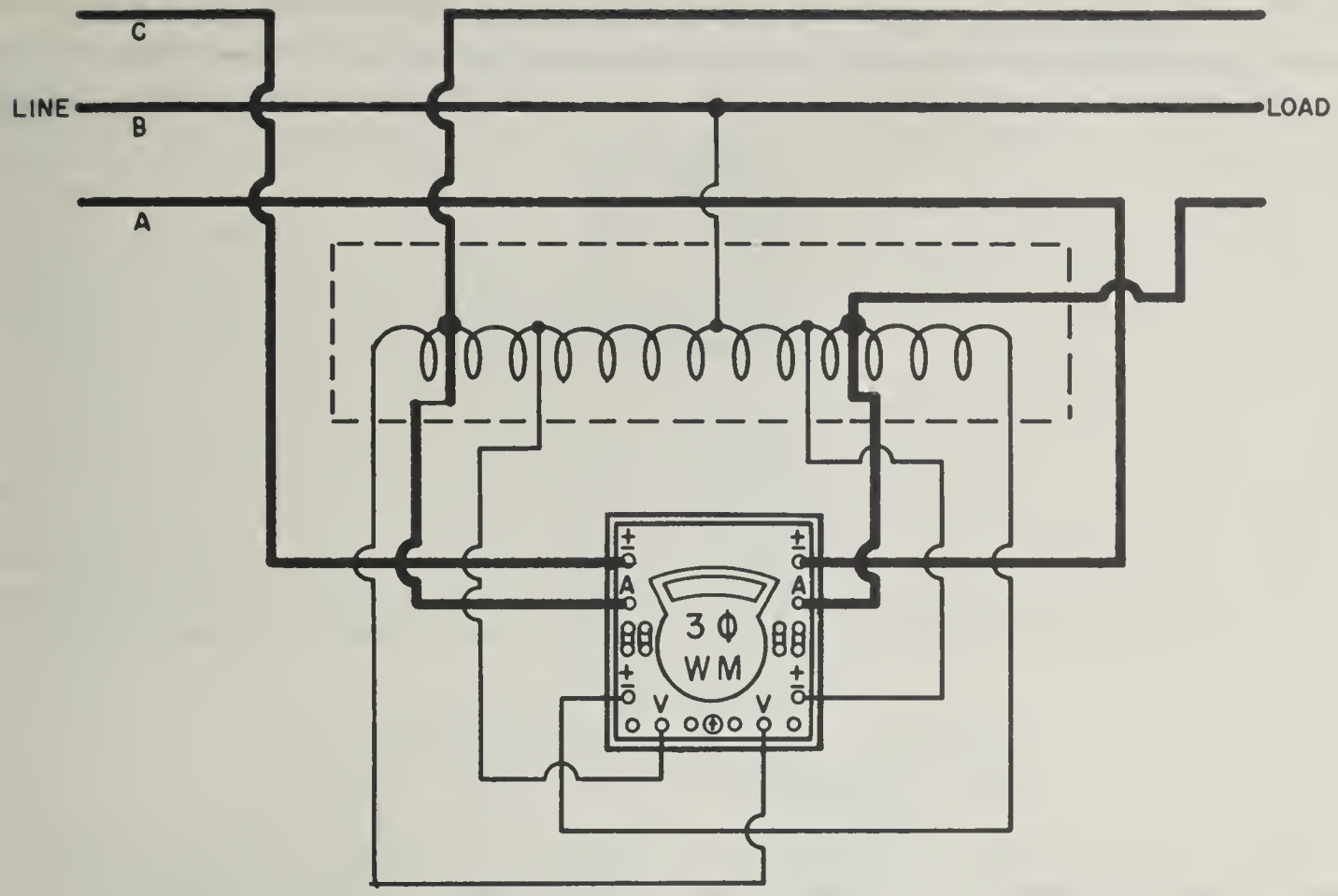



*Figure 205.1–XXXVII. Polyphase varmeter circuit.*

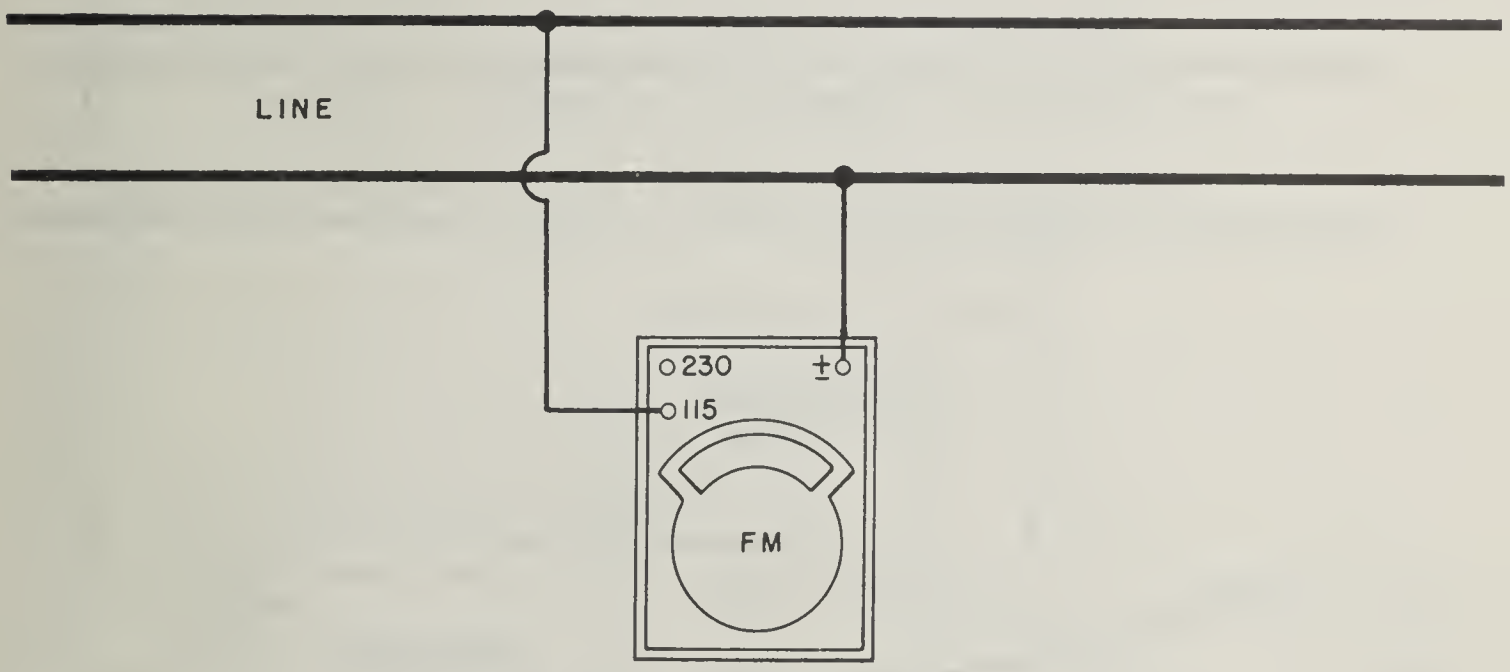



*Figure 205.1–XXXVIII. Frequency meter.*

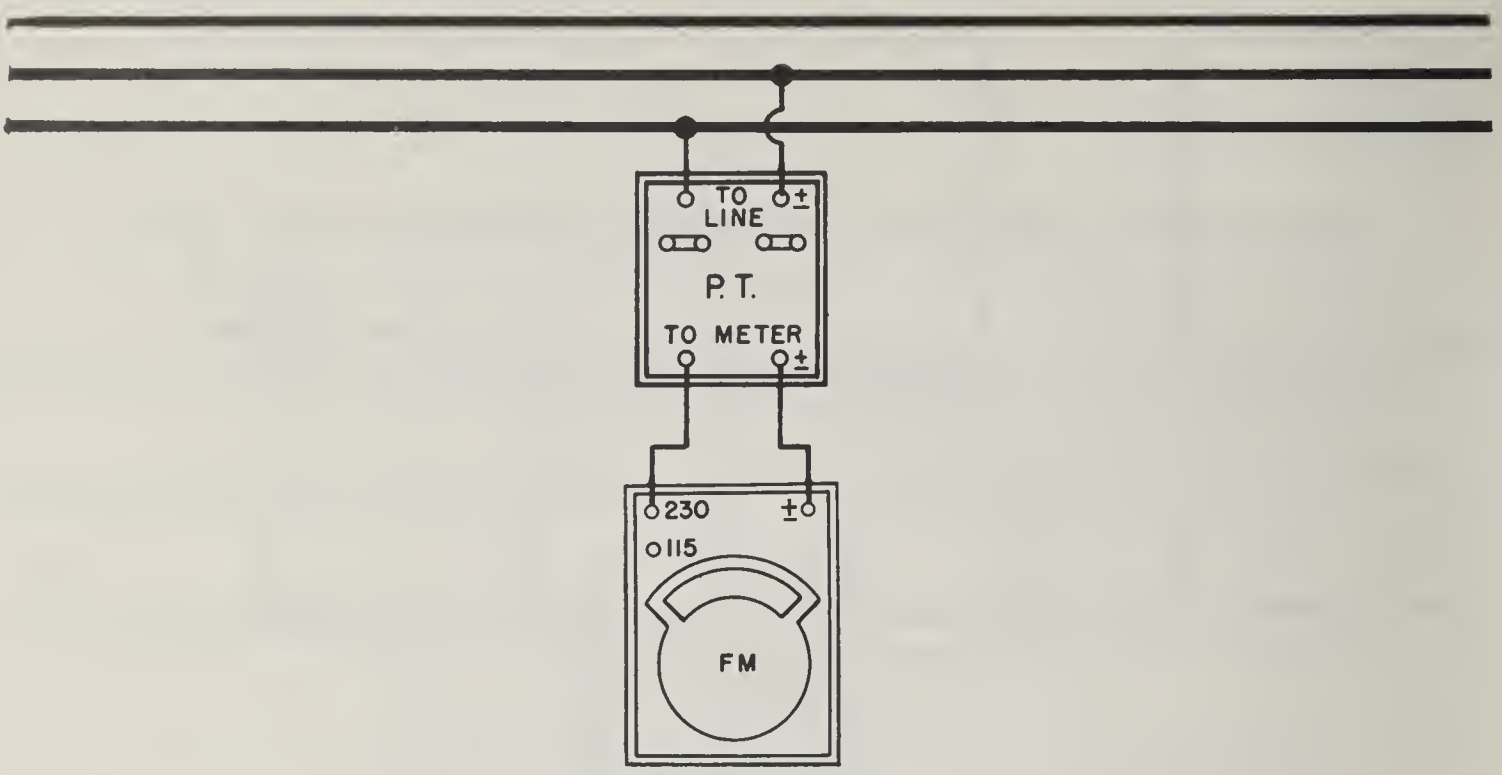



*Figure 205.1–XXXIX. Frequency meter with potential transformer.*

Figure 205.1–XL shows the connections for a recording frequency meter with an external impedor. Most indicating frequency meters have this circuit element built into the case. However, where it is supplied to be used externally, it is calibrated for a particular instrument and must always be used with that instrument.

The accuracy of frequency meter readings is influenced by the waveform of the circuit potential. When the waveform differs substantially

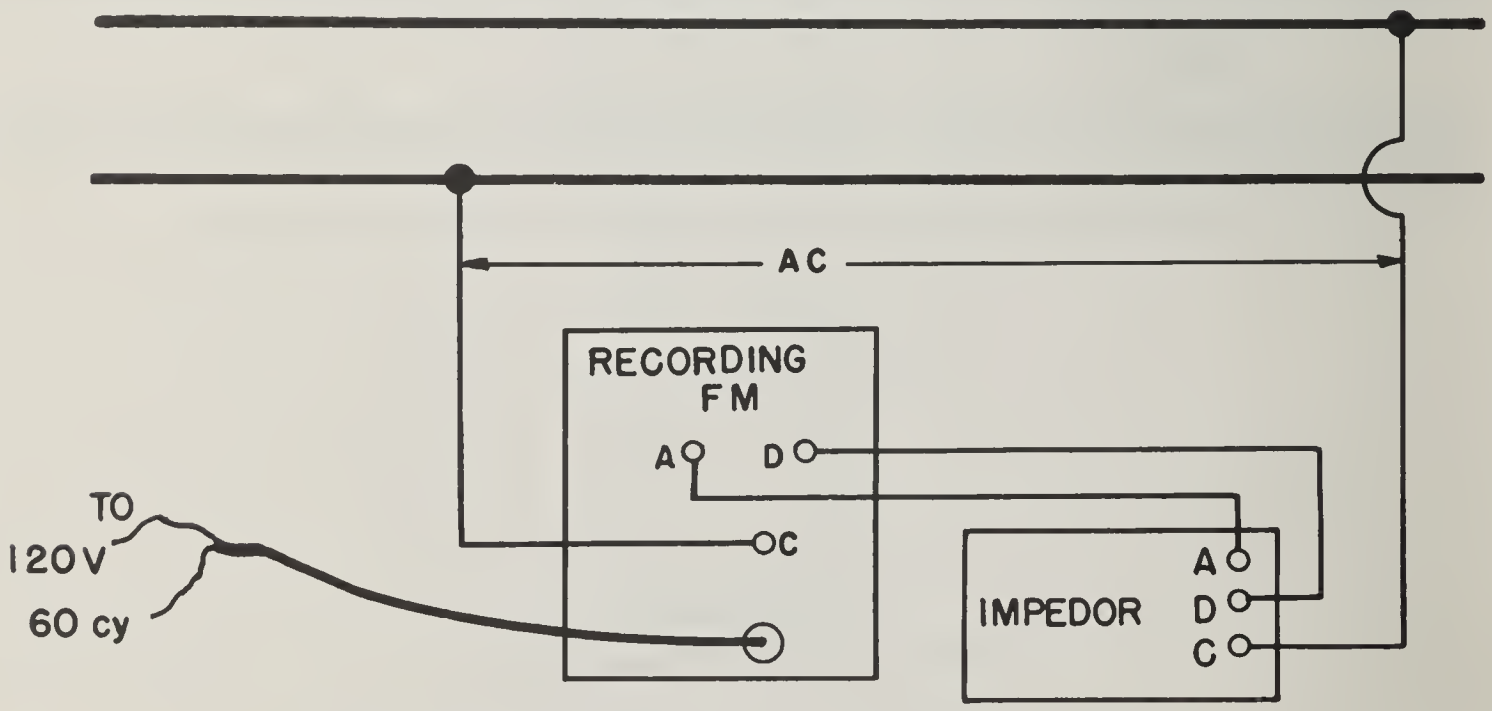


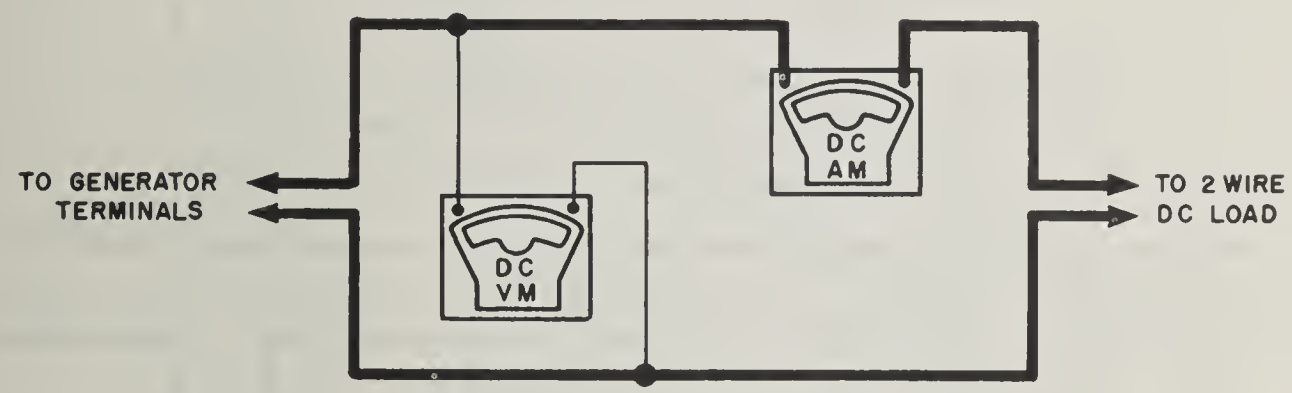

*Figure 205.1–XL. Recording frequency meter with external impedor.*

from that of a sine wave, the readings will be erroneous. When it is desired to read the frequency of nonsinusoidal waves, special instruments, containing band pass filters, must be used. Since the specifications for engine-generators always require good waveform, these special instruments are not needed when the frequency is determined directly from the line voltage of the generator. They may be needed, however, if the rotational speed of a generator set is determined by the use of a frequency meter and an electrically overloaded tachometer generator.

***Caution:*** **To prevent damage to frequency meters, they should only be electrically connected to the line when the line frequency is known to be within the range of the instrument. Most frequency meters are equipped with an on-off switch for this purpose.**

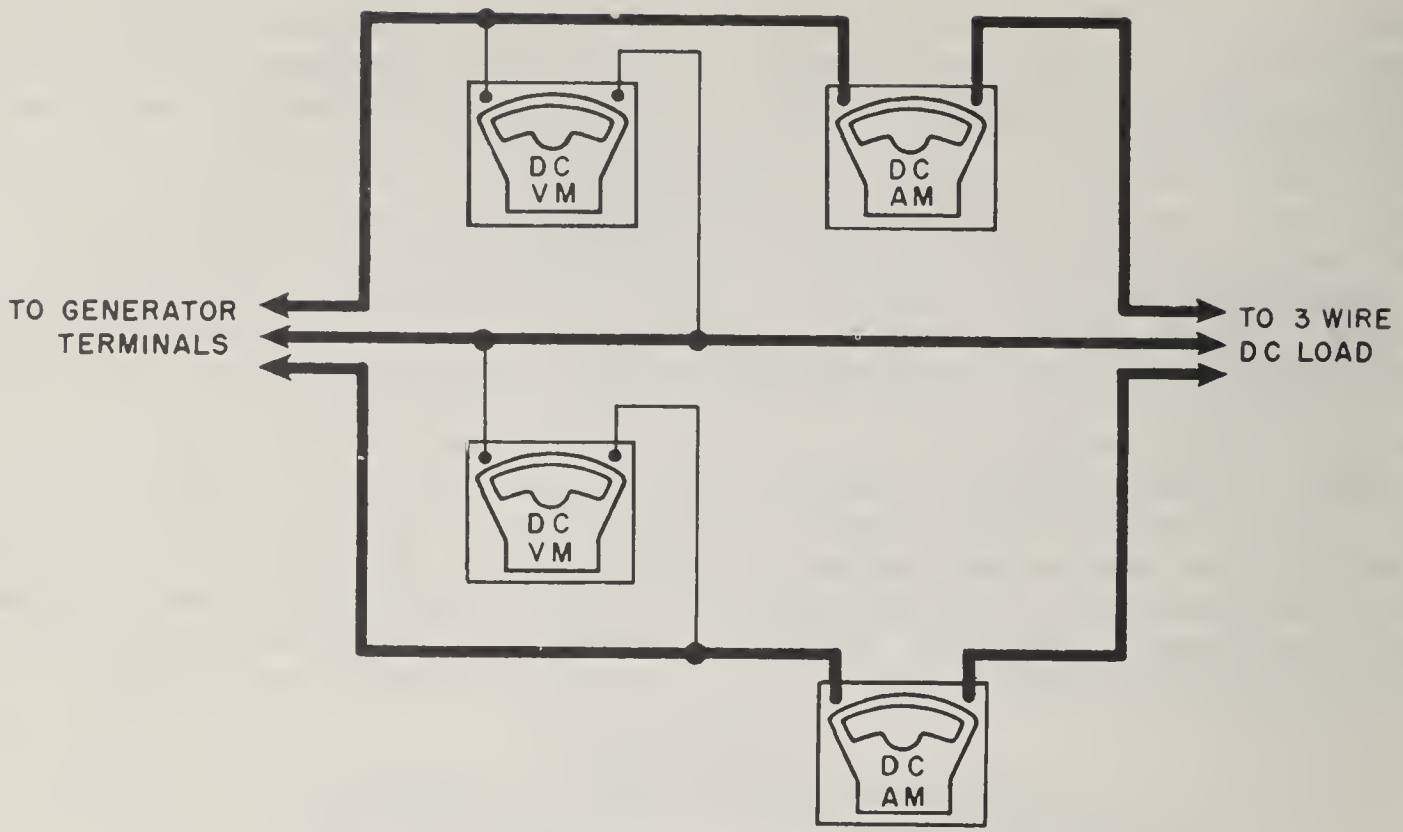
### 205.1.10 Load Instrumentation

Figures 205.1–XLI through 205.1–XLVI show methods of using instruments in combination to measure the load conditions on a generator. In order to simplify the diagrams, in some instances, instruments are shown without transformers or other multipliers and, therefore, the wiring principles for such accessories given in the preceding paragraphs will have to be used, where necessary, to extend the instrument ranges. The hook up shown in figure 205.1–XLV for a three-wire, three-phase, ac generator set may be used on a four-wire generator set if the loads are balanced. In that case, no connections will be made to the fourth wire (neutral). The instrumentation of figure 205.1–XLVI is necessary only where unbalanced loads are used and the methods of this handbook ordinarily do not call for such conditions.




NOTE: A TACHOMETER FOR DETERMINING THE GENERATOR SPEED IS REQUIRED BUT NOT SHOWN.

*Figure 205.1–XLI. Load instrumentation for two-wire, dc generator set.*




NOTE: A TACHOMETER FOR DETERMINING THE GENERATOR SPEED IS REQUIRED BUT NOT SHOWN.

*Figure 205.1–XLII. Load instrumentation for three-wire, dc generator set.*

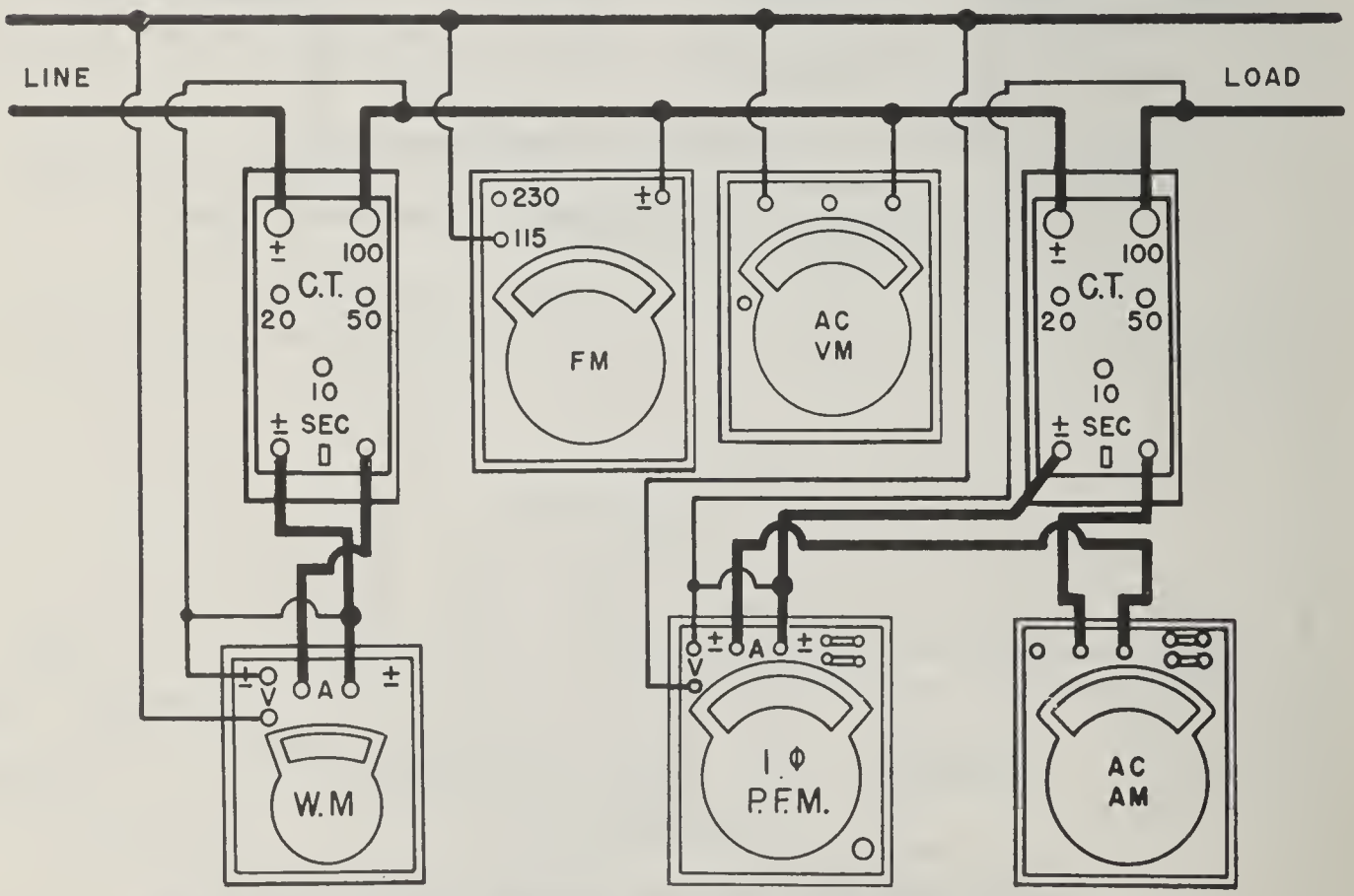



*Figure 205.1–XLIII. Load instrumentation for two-wire, single-phase ac generator set.*

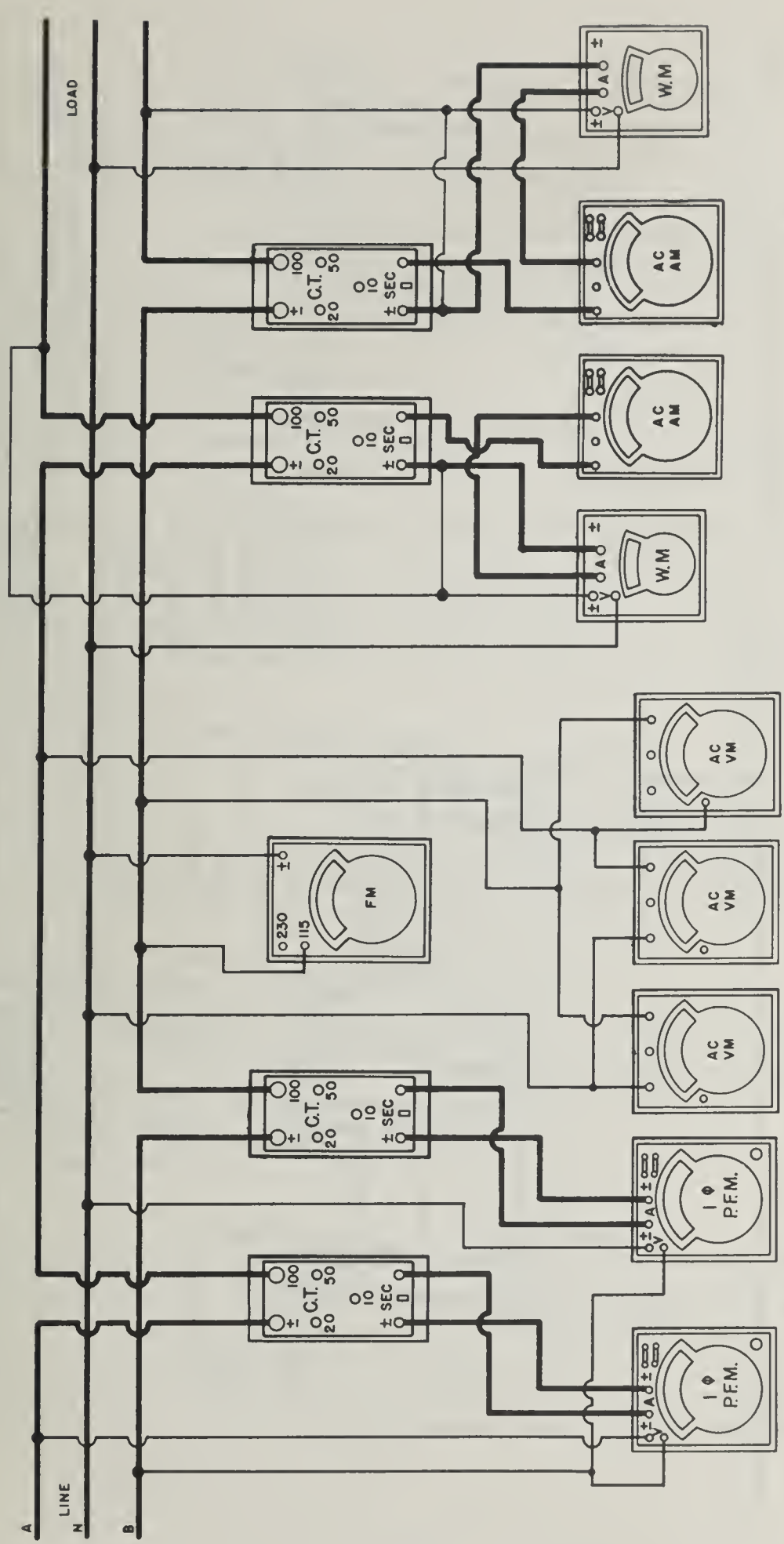



*Figure 205.1-XLIV. Load instrumentation for three-wire, single-phase ac generator set.*

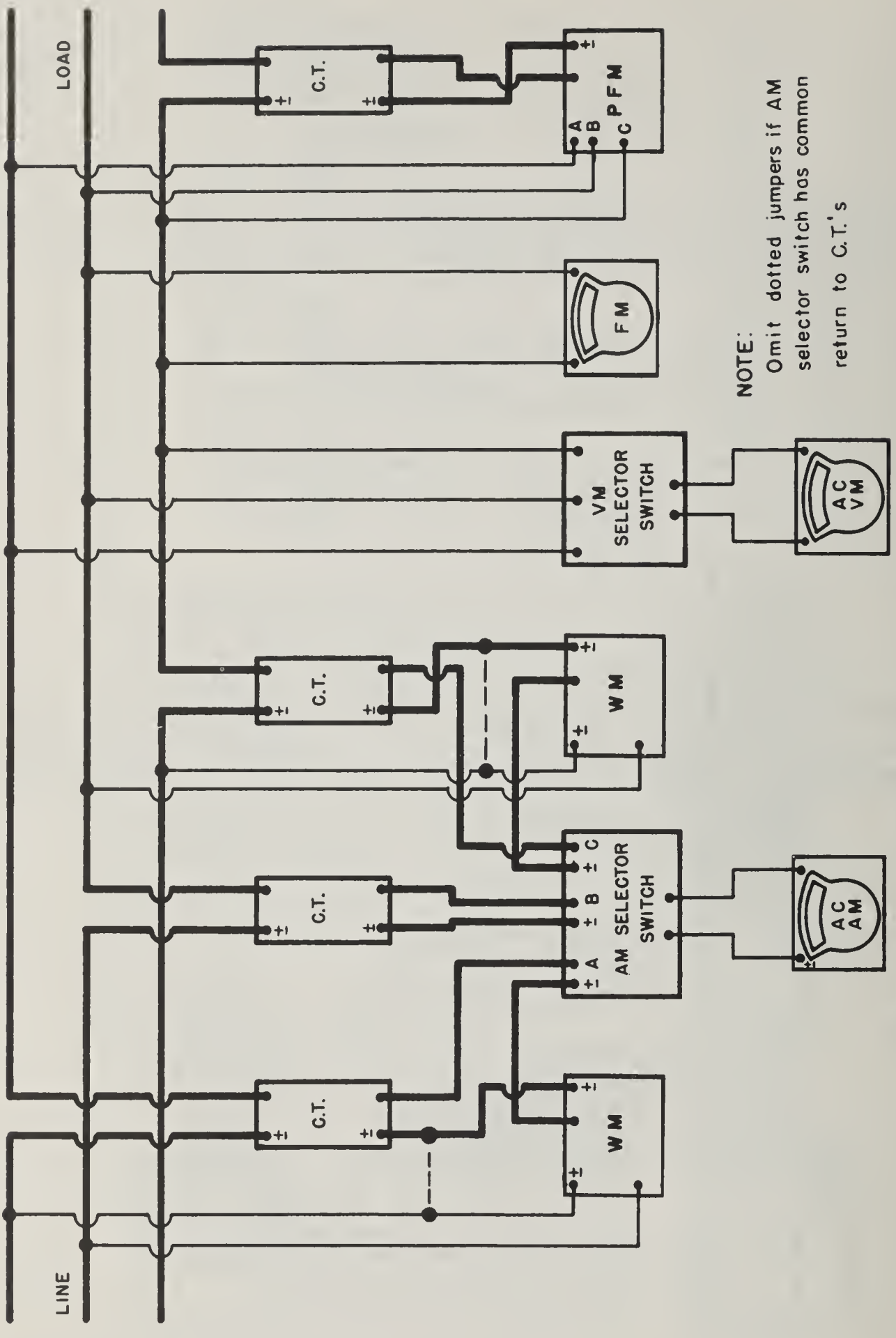



*Figure 205.1-XLV. Load instrumentation for three-wire, three-phase, ac generator set.*

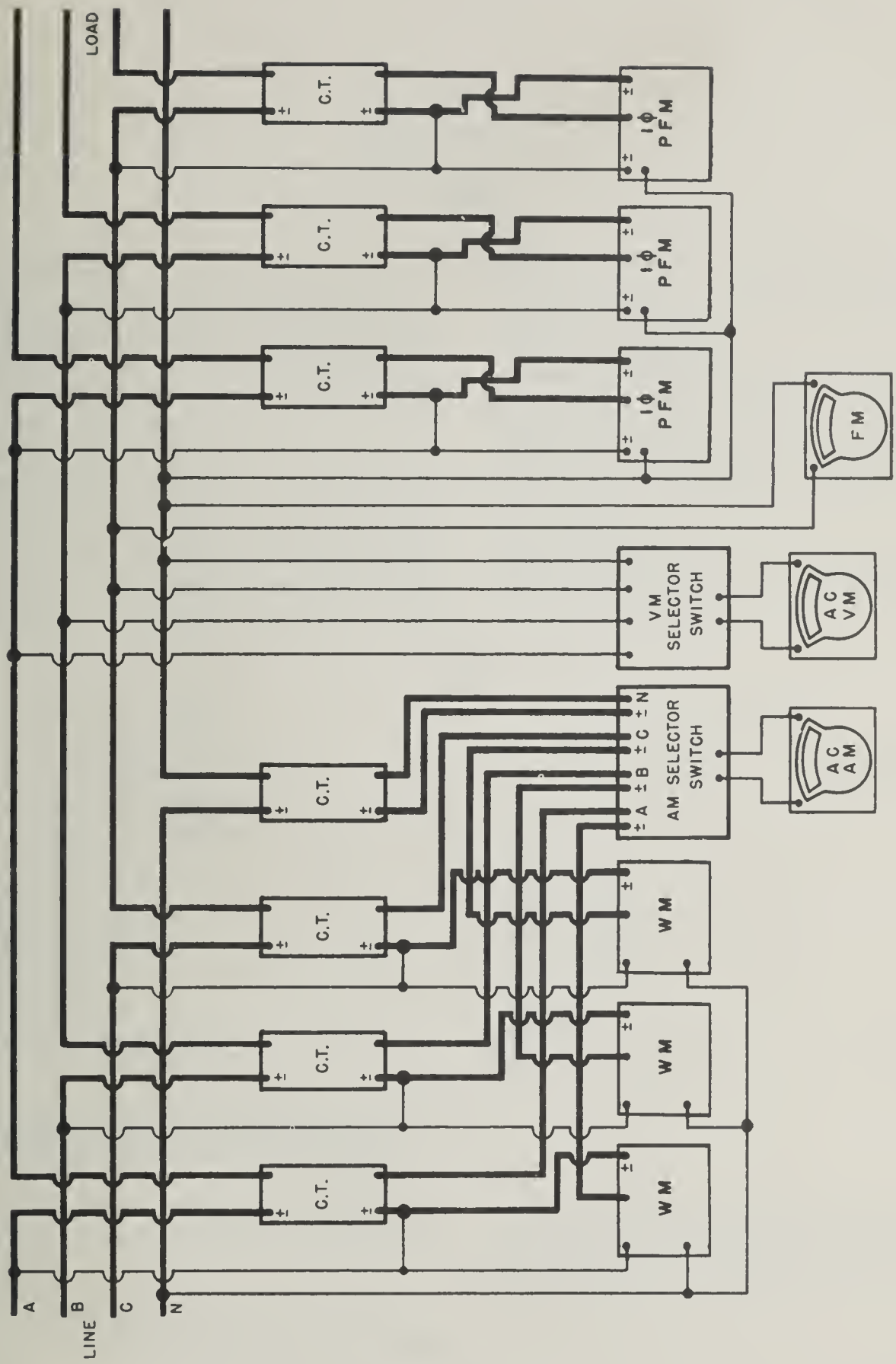



*Figure 205.1–XLVI. Load instrumentation for four-wire, three-phase, ac generator set.*

# METHOD 210.1

# FUELS

## 210.1.1. General

In order to obtain comparative results, tests on engine-generator sets must be made with fuels with controlled characteristics. Unless otherwise specified in the procurement documents, the fuels specified herein shall be used in the performance of the tests in MIL–STD–705.

Certified analyses of the fuels usually can be obtained from the suppliers. If certified analyses cannot be obtained, samples should be sent to a materials laboratory to test for compliance with the applicable specifications. Copies of these analyses should be appended to the final report of the complete tests on the engine-generator set.

## 210.1.2 Gasoline

Gasoline used in tests shall conform to the appropriate specification and to additional analyses requirements shown in table I of this method. For 2-cycle engines requiring a gasoline-oil mixture, the mixture ratio shall be as specified by the engine manufacturer.

It should be noted that the analyses of fuels listed in the table are more restrictive than the analyses of the basic specification for the fuels.

*Table I*

| Test use | Performance and endurance tests | | Low-temperature tests |
|---|---|---|---|
| Specification grade or type | MIL–G–3056 type I | MIL–G–5572 grade 100/130 | MIL–G–3056 type II |
| Restrictive conditions in addition to specification requirements: | [1] | | |
| Distillation | ASTM 216 | | |
| 10% evaporation | 140° to 158° F | | |
| 50% evaporation | 194° to 239° F | | |
| 90% evaporation | 275° to 356° F | | |
| Octane number: | | | |
| Motor method | 83 to 85 [3] | | |
| Research method | 91 to 93 [3] | | |
| TEL content ml/US gal [2] | 2.5–3.0 [4] | 4. 0–4. 6 | |

[1] Equal to Ordnance Referee Fuel.
[2] As determined by Method 5501 of Federal Standard 791.
[3] Not required for endurance test in Corps of Engineers application.
[4] Required for endurance test only in Corps of Engineers application.

Except for the above restrictive analysis conditions, all other requirements of the specifications are applicable.

## 210.1.3 Diesel Fuel

Diesel fuels used in the performance of tests called for in this handbook shall conform to the requirements of the Federal Specification for Fuel Oil, Diesel VV–F–800, and the additional requirement contained in table II of this method.

*Table II*

| Test use | Performance and endurance tests | Low temperature tests | |
|---|---|---|---|
| Test temperature | +20° F. to 125° F. | −25° F. to +19° F. | −65° F. to −20° F. |
| Specification and grade of fuel | VV-F-800 Grade DF-2 (Regular) | VV-F-800 Grade DF-1 (Winter) | VV-F-800 Grade DF-A (Arctic) |
| Restrictive conditions in addition to specification requirements: | | | |
| Sulphur, percent | 0.95 to 1.05 | | |

Diesel generator sets for the Bureau of Ships should be tested using applicable Navy fuel covered in Specification MIL–F–16884 (Ships) unless otherwise specified in the procurement document.

# METHOD 211.1

# LUBRICATING OILS

## 211.1 General

In order to insure uniformity of testing, the following lubricating oils will be used in the performance of the test methods of this handbook, unless otherwise specified in the procurement document.

| *Specification* | *Grade* | *Use* |
|---|---|---|
| MIL–L–2104 | OE–30* | For tests above 32° F. |
| MIL–L–2104 | OE–10 | For tests −10° to 32° F. |
| MIL–L–10295 | OE–S | For tests below −10° F. |
| MIL–L–6082 | 1065 | When using fuel conforming to MIL-G–5572. |
| MIL–L–9000 (NAVY) | -------- | ---------- |

Analyses of the oils used usually can be obtained from the suppliers. If analyses cannot be obtained, samples should be sent to a materials laboratory to test for compliance with the applicable specifications. Copies of the analyses or QPL certifications should be appended to the final report on the complete tests on the engine-generator set.

**Note.* For performance and endurance tests at ambients above 32°F., only lubricating oil conforming to MIL–L–2104 and listed in QPL–2104, Qualification number M–557 will be used (except when fuel conforming to MIL–G–5572 is used).

# METHOD 220.1

# ENGINE PRESSURE MEASUREMENTS

## 220.1.1 General

To obtain a high degree of operating efficiency in an engine, pressures at air intake and at exhaust must be maintained within specified limits. The procurement documents give the requirements for air intake and exhaust gas pressures at various conditions of operation.

## 220.1.2 Air Intake Pressure

*220.1.2.1 Gasoline Engines*

The intake manifold pressure will be measured by a manometer connected to a pressure tap located approximately 2 inches from the carburetor flange. On small engines where a pressure tap may interfere with carburetion, the intake manifold pressure data may be omitted at the discretion of the testing agency. The pressure will be measured in inches of mercury.

*220.1.2.2 Diesel Engines*

Pressure of the intake air in the manifold for naturally aspirated engines will be measured by a manometer connected to a pressure tap near the inlet flange of the manifold. For engines with scavenging air blowers or superchargers, the air pressure will be measured by a manometer connected to a pressure tap located on the discharge side of the blower. The pressure will be measured in inches of mercury or water.

## 220.1.3 Exhaust Gas Pressure

The mean exhaust gas pressure will be measured by a manometer connected to a tap located approximately 2 inches beyond the outlet flange of the exhaust manifold or turbocharger. The pressure will be measured in inches of mercury or water. The back pressure imposed by the laboratory exhaust system during tests at rated net continuous load and speed will be not less than that existing at the same load and speed with the set exhausting directly to the atmosphere through only its own exhaust system, and will be increased above this minimum value if a higher test pressure is specified in the procurement documents.

# METHOD 220.2

# PRESSURE AND TEMPERATURE CORRECTIONS TO ENGINE DATA

## 220.2.1 General

The observed value of manifold pressure, as obtained by the procedure outlined in test Method 220.1, includes moisture vapor pressure as well as dry air pressure. To obtain the dry absolute manifold pressure, which is the required condition in some specifications, the observed value will be corrected to exclude that pressure resulting from moisture vapor. Carburetor air inlet temperatures also are a factor in obtaining this correction.

The maximum power value, as obtained in test Method 640.1 of MIL–STD–705, also will be corrected to standard conditions of temperature and pressure.

## 220.2.2 Correcting Intake Manifold Pressure Observation

The moisture vapor pressure for a given combination of temperature and relative humidity will be determined by obtaining wet-bulb and dry-bulb temperatures with a psychrometer (fig. 220.2–I). The psychrometer will be operated near the engine air intake and the readings obtained will be used in connection with U.S. Department of Commerce Weather Bureau Psychrometric Tables, Publication No. 235, to obtain the moisture vapor pressure. Subtract the moisture vapor pressure from the observed value of the manifold pressure to obtain the dry absolute manifold pressure at the *observed* temperature. The dry absolute manifold pressure at the *observed* temperature will be converted to a dry absolute manifold pressure at the standard carburetor inlet temperature of 60° F. by applying the following formula:

$$D.A.M.P. \text{ at } T_s = D.A.M.P. \text{ at } T_o\left(\frac{520}{T_o + 460}\right)$$

where:

$D.A.M.P.$ is the dry absolute manifold pressure

$T_s$ is the standard carburetor inlet air temperature (60° F.)

$T_o$ is the observed temperature

## 220.2.3 Correcting Maximum Power Values

All values of observed engine-generator set power output will be corrected to standard conditions of pressure and temperature (sea level, and 60° F.), unless otherwise specified in the procurement document. Correct the observed engine-generator set power output value by applying the following formula:

$$\text{Corrected } KW = (\text{Observed } KW)\ \frac{29.92}{B-E}\ \sqrt{\frac{460+T}{520}}$$

where:

$B$ is the barometer inches of mercury (corrected for temp.)

$E$ is water vapor pressure (inches of mercury)

$T$ is intake air temperature (degrees F.)

29.92 is standard sea level dry air pressure (inches of mercury)

520 is absolute temperature at 60° F. air temperature.

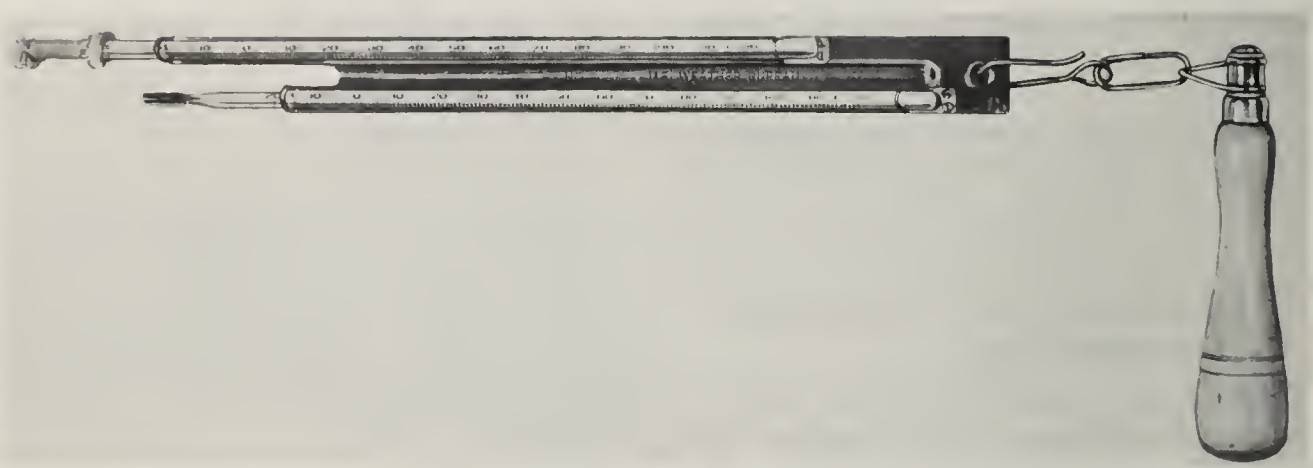


*Figure 220.2–I. Sling psychrometer.*

# 6. ALPHABETICAL INDEX


| Method | Method No. |
|---|---|
| Current, measurement | 102.1 |
| Data sheets | 203.1 |
| Frequency, measurement | 104.1 |
| Fuels | 210.1 |
| Gas analysis, exhaust | 113.1 |
| Instrumentation, electrical | 201.1 |
| Instrumentation, thermal | 202.1 |
| Oils, lubricating | 211.1 |
| Phase rotation, determination | 116.1 |
| Potential, measurement | 101.1 |
| Power measurement | 103.1 |
| Power factor, measurement | 107.1 |
| Pressure, engine, measurement | 220.1 |
| Pressure, measurement | 112.1 |
| Pressure and temperature corrections to engine data | 220.2 |
| Resistance, measurement | 105.1 |
| Sound level, measurement | 115.1 |
| Speed, measurement | 109.1 |
| Temperature control | 114.1 |
| Temperature, measurement | 110.1 |
| Test reports | 204.1 |
| Testing instruments, general instruction for connecting | 205.1 |
| Time, measurement | 108.1 |
| Waveform and transient, measurement | 106.1 |
| Weight and force, measurement | 111.1 |

# 7. NUMERICAL INDEX

| Method No. | Method |
|---|---|
| 101.1 | Measurement of potential. |
| 102.1 | Measurement of current. |
| 103.1 | Measurement of power. |
| 104.1 | Measurement of frequency |
| 105.1 | Measurement of resistance. |
| 106.1 | Measurement of transients and waveform. |
| 107.1 | Measurement of power factor. |
| 108.1 | Measurement of time. |
| 109.1 | Measurement of speed. |
| 110.1 | Measurement of temperature. |
| 111.1 | Measurement of weight and force. |
| 112.1 | Measurement of pressure. |
| 113.1 | Exhaust gas analysis. |
| 114.1 | Temperature control. |
| 115.1 | Measurement of sound level. |
| 116.1 | Determination of phase rotation. |
| 201.1 | Electrical instrumentation. |
| 202.1 | Thermal instrumentation. |
| 203.1 | Data sheets. |
| 204.1 | Test reports. |
| 205.1 | General instructions for connecting testing instruments. |
| 210.1 | Fuels. |
| 211.1 | Lubricating oils. |
| 220.1 | Engine pressure measurements. |
| 220.2 | Pressure and temperature corrections to engine data. |

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